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BOTANY FOR FUN

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BREAD
A FEW OF THE THINGS PROVIDED BY PLANTS
PURE WOOL

'We arrive at the astonishing truth that we depend entirely—directly or indirectly—on the vegetable kingdom for the food that makes our existence possible' (p. 79).

BOTANY FOR FUN

By

GARETH H. BROWNING

With over 180 Drawings and a Frontispiece by

CECILE M. DRIFFIELD

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AUTHOR'S NOTE

This little book is designed to engage the interest of young people in the story of plant-life. The subject is full of fascination, and the author has embarked on it with the determined intention (so far as his ability will allow) of avoiding the common treatment which renders it dry and unpalatable by the use of indigestible technical terms and the creation of a stuffy classroom atmosphere. The last thing that the volume is intended to be is a text-book. Rather, it is hoped, it will be regarded as an outline of the subject—and a fairly full and serviceable one—which should form agreeable reading to any child of ordinary intelligence, and incite those whose interest is sufficiently aroused to pursue the study further with the aid of some of the more formal works. With this end in view, the author has not scrupled to interrupt the narrative for play-time intervals of lighter matter, even to the inclusion of nonsense rhymes.

Books by the same Author

THE CHILDREN'S BOOK OF WILD FLOWERS

THE CHILDREN'S STORY BOOK OF BEES

MAGIC IN THE WOODS

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BOTANY FOR FUN

CHAPTER I

HOW THE PLANTS SET ME SOME FASCINATING PUZZLES

When I was eleven, my sister Janet (who was only ten) used to get considerably puzzled about the plants growing in our garden in London, and of course about the wild flowers we saw when we spent the summer holidays in the country. It was, indeed, Janet who started the trouble for both of us, because I should not have bothered my head about such things. Only she was always poking about amongst the flowers in the garden and making old Angus, our gardener, frightfully angry by treading down the beds. He was a Scotsman, with wild-looking, sandy hair that grew out on all sides like a well-lit bonfire, and blue eyes that used to blaze like no bonfire that ever was. When he caught Janet galumphing about amongst his prize roses and tulips, he would clench his fists and roar out, " Awa' oot o' that, ye wee limmer! Gin ye pit yer muckle feet on ma braw beds, ah'll sort ye! Awa' noo, or ah'll skelp ye! "

It was great fun to see him stamping about, pink in the face and snorting like a vicious little terrier, while Janet would try to look haughty at his rudeness and open her eyes in innocent surprise at observing that her clumsy feet had wrecked his flowers. One day, I remember, he went rampaging off with her to tell Mummy about it, though that didn't worry Janet much, for all Mummy said was, " Janet darling, you *should* be careful not to spoil the flowers. Angus takes a lot of trouble over them."

" But, Mummy," said Janet, " I wanted to know . . ."

" What did you want to know? " Mummy asked. (She had an awfully gentle sort of voice, you know. It never got angry, and you felt that you wouldn't ever like to do anything that *ought* to make her angry.)

Geranium

Well, then Janet screwed up her eyebrows and started squirming about in a silly way she had, and digging holes in the gravel path with her toes—which made old Angus more furious than ever. And, while he was muttering hoots and havers under his breath, she suddenly burst out:

"Well, I wanted to know *why* the roots always go down into the ground. And *why* there aren't any leaves and flowers on them. And *why* there aren't any seeds unless the flowers come first. And where the seeds come from. And how the flowers make honey. And—and —oh lots and lots of things."

It was glorious to see old Angus then, spluttering out "Guid sakes! Did ye ever hear-r sich blethers?" while Mummie just smiled and tried to explain to Janet *why* the plants behaved as they did. Only somehow she didn't seem to answer the questions very clearly, and all we could gather was that the plants somehow managed to get their 'food', as she called it, from the soil. I thought they were childish questions myself, because naturally a plant has to send its roots downwards, or how could it grow? And what would be the use of having leaves and flowers underground? But, as to the seeds not coming unless there were some flowers first, and how they came at all—well that did seem a bit curious perhaps. And, when you came to think of it, perhaps the other things were curious too. Roots always did grow downwards, of course; but what made them do it, and what sort of 'food' they found in the soil, was rather a puzzle.

There was one awful day when Janet started making experiments. She sneaked into the greenhouse when Angus was away and pulled up some young Geraniums he had in pots there. Then she stuck them back again with the stems and leaves in the soil and the roots in the air.

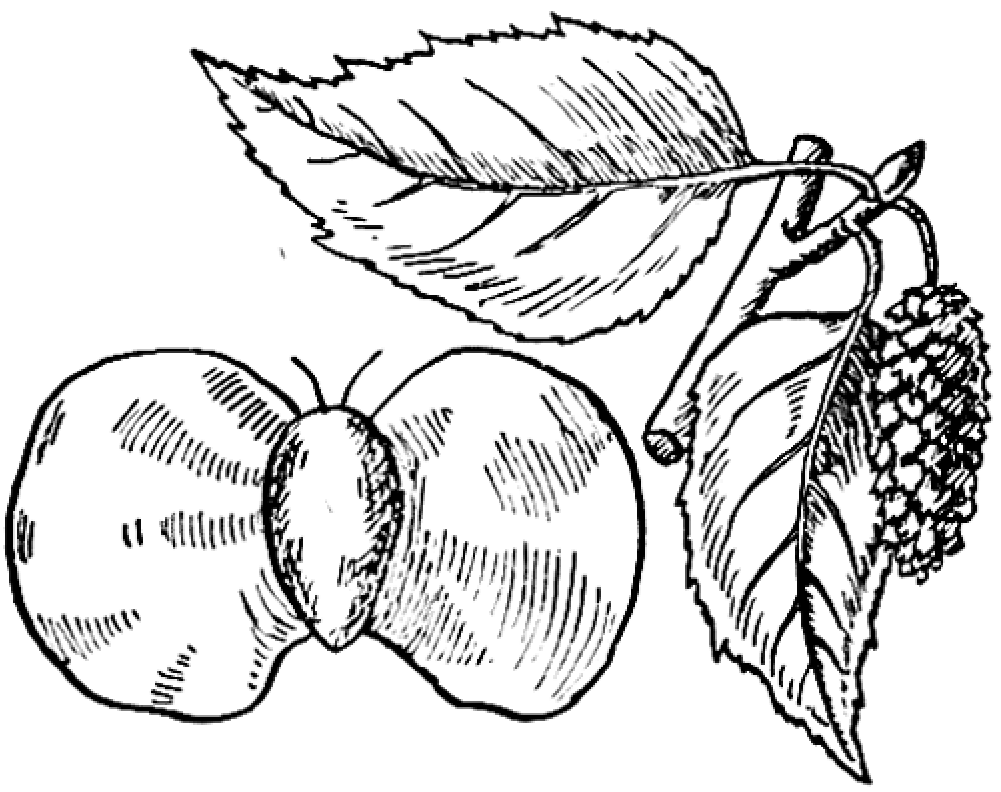
Janet Plants the Geranium Upside Down

"Gee!" I said, "now you've done it. Wait till old Angus sees them."

"I don't care," declared Janet. "It'll be fun to see what they do." Then she began to giggle. "Don't they look like funny old men fallen head first into a ditch with their legs waggling in the air! "

They did rather, but Angus didn't see that side of the picture when he returned. Janet had to skip away pretty quickly or I believe he'd have tanned her. And the only result of her experiment was that Mummy put the greenhouse out of bounds.

But there were a lot more things than that, I soon gathered, that Janet was puzzling her small brain about. How a Dandelion, for instance, changed itself from a yellow flower into a ball of grey down made up of scores of marvellous little parachutes, each one carrying a seed. How the Gorse on the common shot its seeds out of the black pods like cannon, and why it did it. What effect it had on the flowers when the bees came fussing about them and forced their clumsy way in through the front door and into the sitting-room, as it were. Why Oak trees and Beeches and Hazels produced such quantities of nuts, seeing that a great part of them were simply devoured by pigs and human beings, and thus could be of no service to the tree.



"BUTTERFLIES GROWING ON THE BIRCHES"
(Fruit is greatly magnified.) The seed has two wings.

There certainly seemed to be quite a lot of secrets about plants, and, after a bit, I found myself getting almost as curious as Janet about them. We tried questioning Mummy once or twice, but what she told us didn't seem to make things much clearer, and at last (although we didn't like to put it in so many words to each other) I think we both came to the conclusion that grown-ups, even when they are your own parents, don't know everything. Of course if Daddy had been there he would have been able to explain everything, but Daddy had never come back from the War.

I expect I should have dropped the whole subject if Janet hadn't kept on worrying me about it and raising all sorts of fresh problems which no one seemed able to answer. Her latest teaser was something like this: " If you have your head chopped off, like Charles the First, you can't grow a new head, can you? "

And when I burst out laughing and said: " No, you fathead, you jolly well die," she shouted back:

" Well, then, how is it that, if you chop a tree's head off, it grows a whole heap of new shoots and doesn't seem to mind a bit? Fathead yourself! "

This was absolute rot, of course, but it just shows the way she kept bombarding me with questions I couldn't answer. Another day she came dancing up in a state of huge delight and teased me by saying that there were millions and millions of tiny butterflies *growing* on the Birches on the common near our home, and I could come and find them for myself if I was clever enough. I guessed she was ragging, though it wasn't April Fool's day; but I dashed off with her to the common, and searched all over the Birches, while she stood by, dancing and squirming in that silly way she had and whooping in triumph. Because, although I climbed several trees, I couldn't find a single butterfly, let alone millions; and Janet behaved like a perfect little beast, and wouldn't show me, although she declared that she was staring hard at them all the time.

Uncle Fred had been luckier than Daddy, for he came back from the War and, although he had been stabbed in the arm during a bayonet attack and simply peppered with shell-fragments, it didn't seem to affect his marvellous strength in the least. He was a Colonel, and he looked about ten feet high, and broad in proportion. Even after he came out of the Army he could make a century (including seventeen fours), and his service at tennis was absolutely smashing. Whenever he came to stay with us the whole household seemed to wake up; he was so full of energy and fun, and you could hear the shout of his jolly laughter from the front garden to the back. He used to eat three eggs and about half a York ham at breakfast, and a whole chicken wasn't anything like enough for the four of us when he was at dinner. You wouldn't think a man like that would care anything about wild flowers or botany; but one day—it must have been when we were two or three years older—I went to look for him, and found him in his room with an enormous microscope and, of all things in the world, a whole litter of plants strewed all over the table.

" Uncle! " I exclaimed. " Do you mean to say you go in for *botany*? "

He slewed round in his chair and sort of looked me all over, his bushy eyebrows drawn together and his eyes keen as a hawk's. " And why not, young fellow? " he demanded.

" Well," I stammered, " I should have thought you'd think it—rather tripe."

" And why should I think it rather tripe? "

I began to feel a bit uncomfortable. " Well," I blurted out, " it's what girls go in for. Janet's always messing about with flowers and asking silly questions about them."

" It doesn't make it tripe just because girls go in for it," answered my uncle. " And besides, it isn't *only* girls that take it up. Don't you know that botany—not just collecting wild flowers and learning their names, mind you—is one of the big sciences, like astronomy and physics and medicine, and that many scientists have to study it as a preparation for their own special work? "

" Oh! " I exclaimed. " I didn't know that."

" No, I thought you didn't. And here's another thing which, naturally, you don't know: there are quite a lot of well-paid jobs, abroad and in the colonies, that are simply waiting for young men with a sound knowledge of botany. Now listen to me, young fellow, I'm going to put you through the third degree." He held up his finger sternly and put on a frightfully fierce expression that made me start grinning. " First of all, Mister Prize-Dunce, do you know that, if it weren't for plants, there wouldn't be any food in the world? "

That was a knock-out blow.

" I thought that'd make you sit up," he remarked, still waggling his forefinger in my face. " Now you realise your tummy's affected, you're inclined to think there may be something in botany, eh? Now—next item. You don't know, do you, that plants supply us, one way or another, not only with the food we eat, from plum-pudding to roast beef, but with our clothes as well, and our furniture, and a lot of the building material of our houses and ships, and a heap of medicines—

though that won't appeal to you much, I daresay? Or that they give us paper for books, coal and wood for fires—for coal is largely formed from the remains of forests that decayed millions of years ago—and a few odd trifles like tea and fishing-rods and cricket-bats, to say nothing of enabling us to keep dogs and ponies. Besides which, they keep the air pure for us to breathe."

Well, that was news to me and no mistake. I had no idea that plants cut such a dash and, of course, it did make botany sound a bit more exciting. Uncle Fred saw my eyes goggling, I suppose, for he got up and poked me hard in the ribs and began to laugh. That made me laugh too, and then he went on to give me a few more shocks by showing what splendid adventurers some of the earlier botanists were.

"You remember Captain Cook's first voyage round the world?" he asked.

"In the *Endeavour*?" I said. "Rather!"

"Well, do you remember one of the men who sailed with him—Sir Joseph Banks? I see you don't. Well, Banks was a keen botanist, but not of the arm-chair, stay-at-home type. He liked a bit of adventure as well, and he sailed with Cook to gratify both tastes. It was Banks who named Botany Bay."

"In Australia—where the convicts were sent?"

"Yes, that's what most people know it by; but it got its name from Banks because he found such a vast number of plants there that no one in England had ever heard of before. Then there was Sir Joseph Hooker. About the middle of the nineteenth century he explored the Himalayas and Sikkim and the passes leading into Tibet, as well as other wild bits of country. He was studying some of the larger problems of natural science, but he and his friends found time to amass a collection of seven thousand plants. But those two are only a few of the band who went out into the unexplored parts of the globe when botany as a science was just beginning. There was a succession of these modest heroes, and they ranged from China to Cape Horn and from the Arctic to the South Sea Islands."

"But did they simply go about looking for new plants, Uncle—or what did they do?"

"Oh, goodness, no! That was only the beginning of their work. They added tremendously to our knowledge of various sciences, such as geology and biology. It's a bit difficult to explain to you, because it's a stiff subject; but the importance of one side of their work is easy to appreciate. They discovered plants with valuable properties—just as Sir Walter Raleigh is said to have discovered the potato, though, as a matter of fact, he didn't—plants that could be used for food and medicine and all manner of useful commercial purposes. And, after they'd discovered them in remote places, they brought them home and had them cultivated here, or helped to transplant them in other countries with a suitable climate, where they would be at hand for general use."

I fell to pondering over this, and then he drew me over to the table and told me to wait while he showed me something.

"When you study botany, old chap," he said, "you're learning something about the wonders of life. A plant's a living thing, just as you are a living thing. They all eat and drink and breathe, and fall sick and cure themselves—or don't—and grow up and have families. The most obvious difference—though it's not the most important one—is that animals can move from one place to another, while plants have to stay put. Though even that's not entirely accurate, because some plants can swim. Plants are chock full of wonders and secrets, only you don't suspect it till you study them. I'll show you something under the microscope presently, and then you'll begin to understand what I mean. And that's the best of botany—you can go out and study plants at close quarters, and actually watch them performing their little miracles."

Then he showed me what a leaf looked like under his microscope, and how thistle-down was changed to a silver jungle. And he cut a stem across and showed me the sap rising from the roots on its way up to the leaves to be made into food. And he had the most marvellous pictures of the 'insides' of plants, and pointed out the parts of the roots where food-supplies were received, the canals through which they travelled to the factories, the factories themselves where the food was manufactured, the warehouses where it was stored and the ventilating system operating everywhere.

After that Janet and I were always in and out of his room when he wasn't too busy, and he brought out other drawings showing how the flowers seemed to *invite* insects to come and take their honey and pollen. And he explained why they did it, and how the wind, and the cows and sheep, and squirrels and mice, and even human beings, were all made use of by the plants to help them to carry on their existence. And one day he showed us some pictures of the pollen tubes travelling down towards the centre of the flower to find some 'egg-cells' and turn them into seeds. And he explained how the seeds grew into new plants, and answered all Janet's questions about 'how' and 'why'. He even showed me where to find the butterflies on the Birches.

"But," he said, "there are lots of secrets that no one has yet discovered. For instance, plants, in some ways, are better chemists than we are. They can do things that all our highly equipped laboratories fail in. So there's a grand opening for you youngsters when you grow up, to take up botany. Make your own experiments, as so many of our big men and women are doing, and—who knows?—you may be the first to find the answer to some of these posers—though that's expecting rather much, perhaps."

Well, we did take it up, in a way, between games and things; and then, when we grew up a bit and left school, we both found that we were still keen, though I'm afraid neither of us has yet made any new discoveries. But one day I thought it would be a fine thing to write a book all about botany for boys and girls who didn't happen to have an Uncle Fred to explain it to them, and that's how I come to be writing to you now. At first Janet and I planned to write the book together, but she always kept going off down side-paths that were fascinating enough, I admit, but led us far away from our proper subject. In the end she lost patience with the work and fell to making up nonsense rhymes about it. Some of them are rather jolly, I think, and she says I must put them in the book. Only you must play fair, and not read them till you come to them, or you will miss their point.

CHAPTER II

LOOKING INTO THE SEED

Most of our familiar plants grow from a seed, so I think it will be a good plan if we begin our study by examining some typical seeds. Then I will describe some of the earliest demonstrations Uncle Fred made of the way they begin to grow. An ordinary Broad Bean was the kind he started with, because it was big enough to enable us to distinguish its different parts clearly. The seeds he used had been bought from a seedsman, and were as dry and hard and unpromising as pebbles; so first of all he soaked a number of them in a basin of water. After a few hours we saw the skins become wrinkled, and then, in a day or so, they were all quite smooth again. They had also become plumper—put on flesh, as you might say—and Uncle Fred explained that this was because of the water they had absorbed. The skin, he said, might be regarded as a sort of overcoat for protecting the parts within. It is, in fact, called the seed-coat.

If you examine a Broad Bean, you will see that, at its thicker end, there is a long scar, usually black. This shows where it was joined to the pod. Just above one end of the scar, on what I will call the front edge of the bean, is a triangular bulge. Uncle Fred took one of his soaked seeds, wiped it dry and gave it a gentle squeeze. Immediately we saw some water appear between the end of the scar and the bulge, and, when we examined this place with a hand-lens, we saw a small hole there.

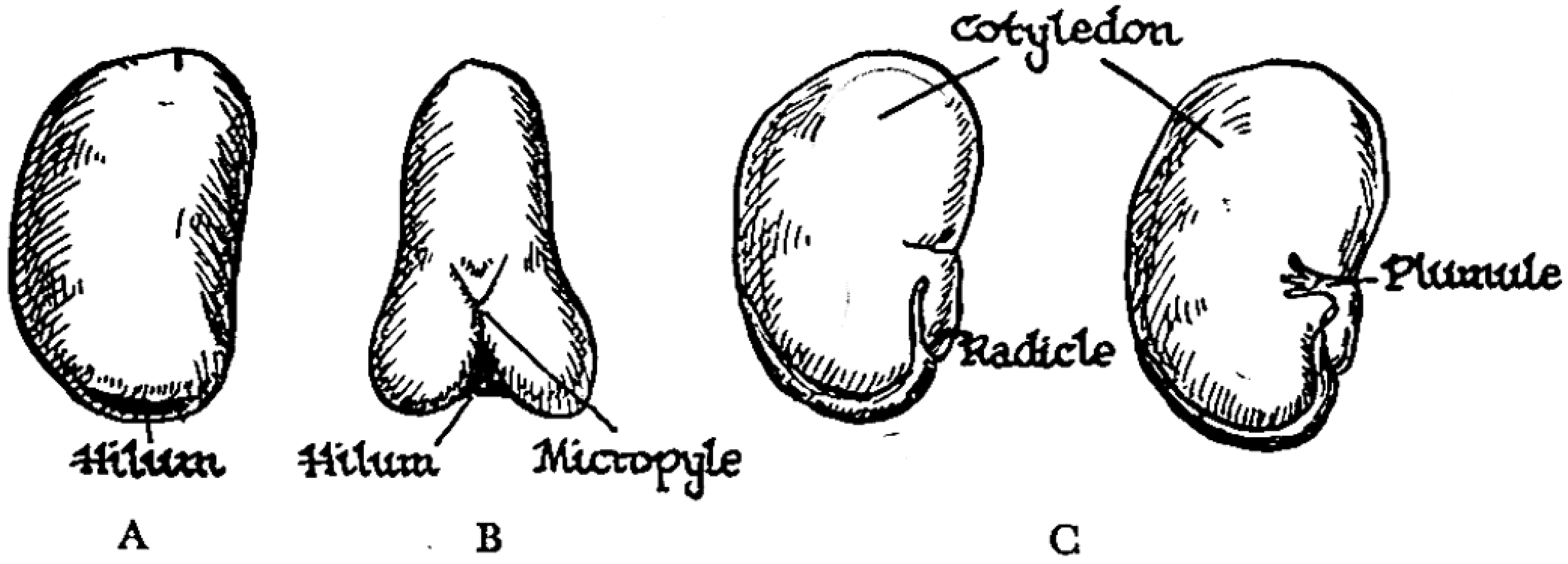
Janet gave a little squeal of excitement. " That's where all the water soaked in, isn't it, Uncle? " she cried.

But she didn't get full marks for that, because Uncle Fred said: " Not *all* of it, Janet. That hole was left in the seed for another purpose, which I'll tell you about some other time. Quite a large proportion of the water did get in that way—

probably about half—but, as a matter of fact, the whole seed-coat is porous, so the water was soaking in all over its surface."

"Not a very good overcoat," remarked Janet. "I wonder what it looks like underneath."

"We can easily tell that," replied my uncle, and promptly took his pocket knife, carefully slit the coat across and stripped it off. We pressed closer to look, and saw two cream-coloured, fleshy lobes pressed so closely together that they looked like one mass, and then Uncle Fred explained what they were. They were the first actual leaves of the plant, but leaves of a special kind and, of course, quite unlike the true foliage leaves that would appear presently. The reason they were so thick and fleshy was that they were crammed with the food that the seedling would need when it began to grow.



A Broad Bean
A. Entire. B. Coat removed. C. Split in two.
Hilum is the scar. Micropyle is the small hole. Cotyledon is seed-leaf.
Radicle is root. Plumule is shoot.

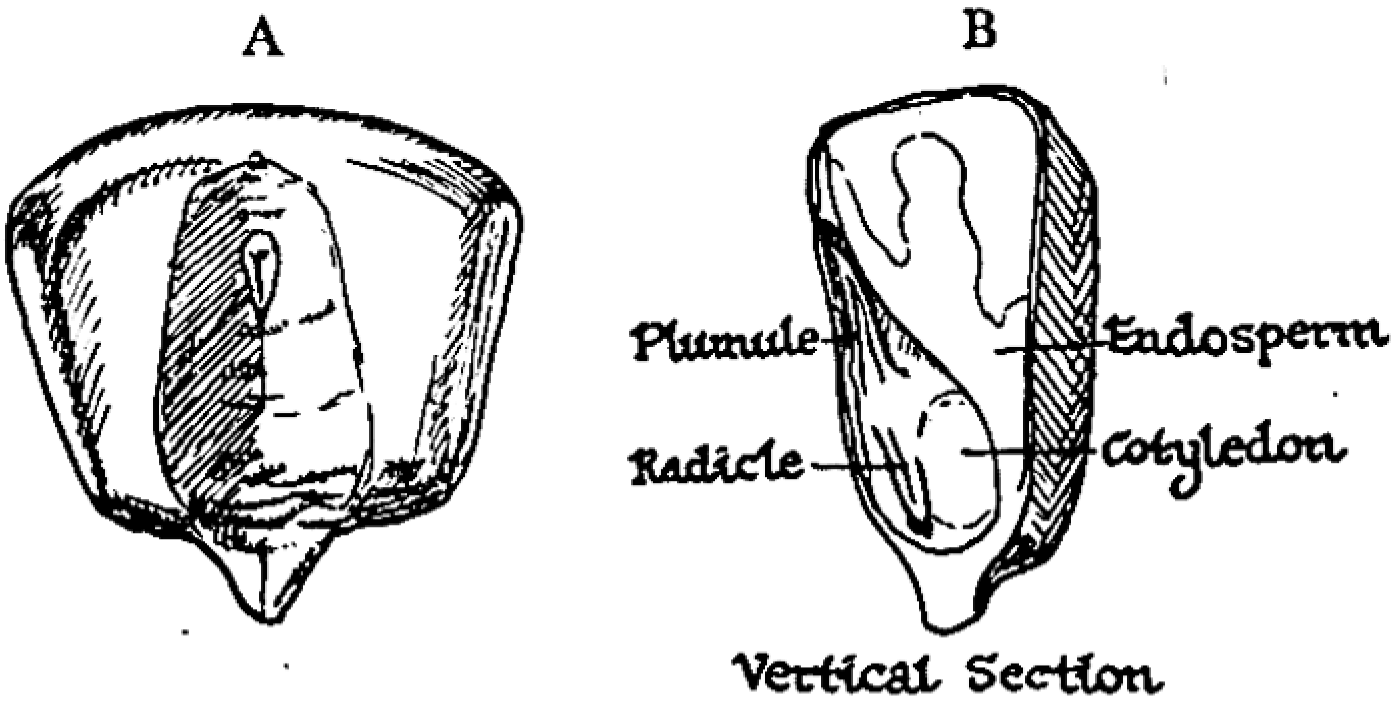
"A time will come," said my uncle, "when it will be ready to make food for itself, but until then, whilst it's still in its infancy, these seed-leaves, as they are called, must serve as its larder. That's one reason why it's fatal to sow seeds too deeply. The food-reserve gives out before the seedling has pushed its stem above ground and begun to cater for itself."

Then he broke the seed-leaves apart, and we could see that, before he had done so, they had each been joined, by a short band or stalk, to a curious little curved object lying between them. This queer-looking object had two parts. The part which pointed downwards towards the thick end of the seed was smooth and tapering. It looked very much like a pointed tooth, but really it was the first root of the plant that was to be. The other part, which had buried its curved head out of sight in little pockets neatly hollowed out of the seed-leaves, seemed to bear some sort of jagged-looking growth at its head. When we took a peep at the head through the lens, we saw that it formed a bud. Uncle Fred carefully opened out the bud with a needle, and then we saw quite plainly that it was, in fact, a collection of tiny, delicate leaves. This part, then, he told us, was the first stem or shoot of the new plant, bearing the first leaf-bud at its tip.

The root, shoot and pair of seed-leaves which we discovered in the seed of the Broad Bean are to be found in the seeds of practically all the other flowering plants that belong to the great group known as the dicotyledons. This is rather a terrifying name, as botanical terms have an unfortunate habit of being, for which reason I shall employ very few of them. 'Dicotyledons' simply indicates that the plants belonging to that group produce seeds containing *two* seed-leaves, 'di' meaning 'two' and 'cotyledon' being the botanical word for 'seed-leaf'. The group includes the great majority of our familiar plants, and is the principal one that we shall study. There are many variations in the parts of different kinds of seeds. For instance, their seed-leaves are often quite differently shaped from those of the Broad Bean. With the exception of one particular feature, however, the variations are unimportant for our present purpose. The feature I refer to is this: In the seeds of some of the plants of this group the food-supply, instead of being stored within the seed-leaves, is placed alongside them. Thus it forms no part of the young plant itself, though it is contained (with the plant) inside the covering of the seed-coat.

This feature, however, appears much more generally in the other group which I now propose to talk about. This is the group of monocotyledons, comprising the plants whose seeds have but one seed-leaf, 'mono' meaning 'one'. It includes, amongst other plants, the Grasses and Rushes; Wheat and 'corn' plants in general; and Orchids, Irises, Crocuses, etc., that produce bulbs and similar structures.

As an example of the "seeds" of this group, we can take a grain of Maize. If you soak and examine a grain (you can get some from a corn-chandler), you will notice that there is a large, oval, whitish patch on one side. This shows the position of the young plant lying beneath the covering coat. If you strip off the coat, you will discover the plantlet, with its root and shoot, lying towards the narrow end of the grain. It is attached to a flat object, like a shield, lying behind it. This we may take to be the single seed-leaf. We can see it well if we cut the grain downwards from back to front, and we can also see that that part of the grain which lies behind the shield is coloured white or yellow. This is the food-reserve, stored outside the plant, but within the covering coat. The duty of the seed-leaf is to draw it into the plant, digest it and pass it on to the root and shoot when they begin to grow. The plantlet itself occupies only a small part of the entire grain, the remaining space being given up to the food-reserve. In a grain of Wheat the plantlet is even smaller in proportion to the food-reserve; and it is this generous store that the farmer steps in and reaps in order to supply us with bread.



A GRAIN OF MAIZE
A. Entire. B. Vertical section.
Endosperm is food reserve.

These different parts of the Maize grain are a little difficult to make out, even with a lens, and, when my uncle was showing them to us, he suddenly strode off to the medicine-chest and brought out a bottle of tincture of iodine. Then he dropped a little on the cut surface of the grain and told us to gather round.

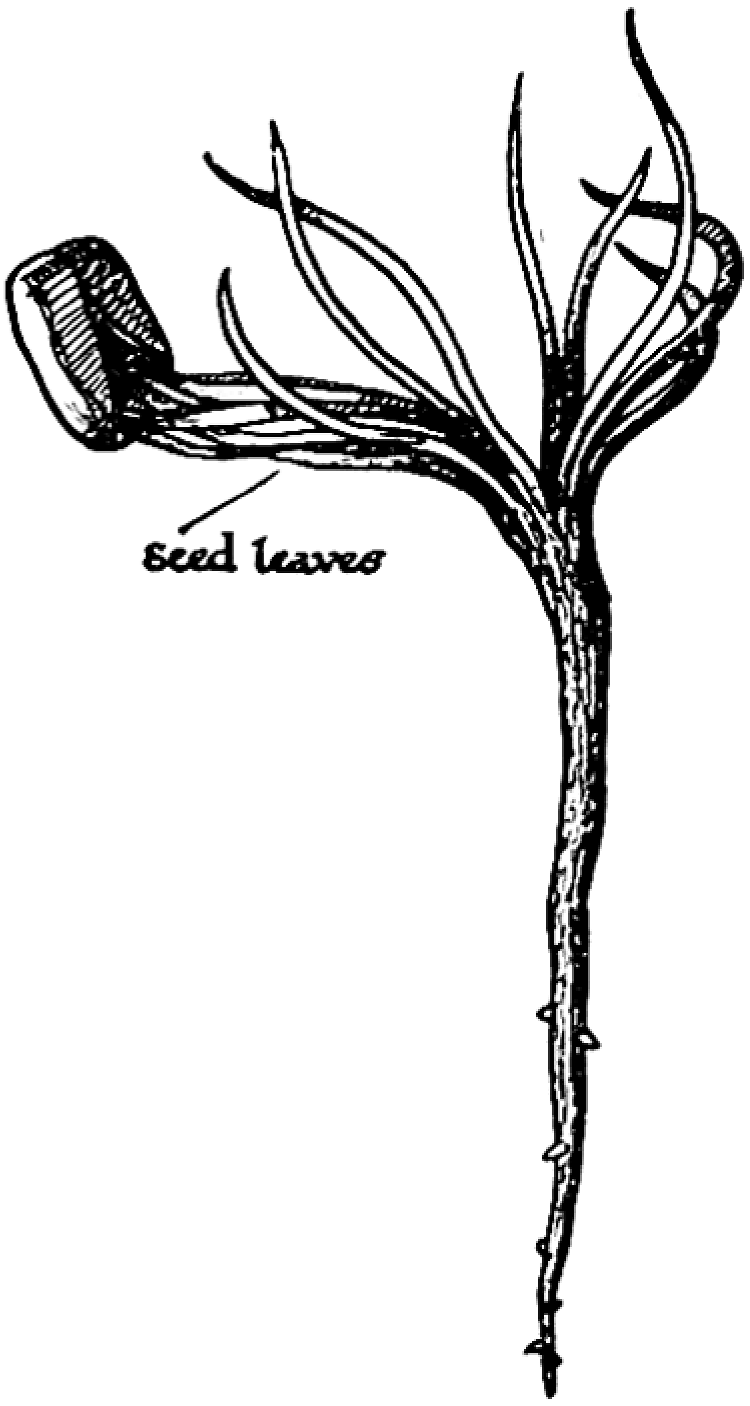
It made everything beautifully clear, because the plantlet itself—root, shoot and seed-leaf—had turned brown, and part of the food-reserve stood out in very dark blue. The reason was, he said, that the food-reserve contained starch, and starch turns dark blue when you treat it with iodine. Botanists, he added, always employ another form of iodine (which you can obtain from the chemist); but the tincture serves almost as well.

"Starch seems a queer kind of food," I remarked.

"I daresay it does," replied Uncle Fred with a smile, "yet you eat plenty of it yourself—when you tuck into bread, or potatoes, or tapioca pudding. They're full of starch, though they don't taste quite the same as the starch used at the laundry."

There are a few plants, such as Pine trees, whose seeds contain more than two seed-leaves; but they are rare exceptions to the general rule, the vast majority of flowering plants producing seeds with only one or two seed-leaves.

We have made a beginning, then, by discovering that a seed is really a plant in itself, complete with root, stem and leaves. It is, indeed, something more, and also something less, than a growing plant; for, on the one hand, it is the fortunate possessor of a well-stocked larder, but, on the other, it is as yet a sleeping infant awaiting the summons to active life.



Pine Seedling

Before we commence the next chapter I think it would be a pleasant change for you to begin making some practical observations and experiments for yourselves. Reading is only a small part of the "fun" of botany. The really fascinating part begins when you go out and study the living flowers and make experiments to illuminate and supplement what you have learned from books. Most of the simple experiments in this book you can repeat for yourselves—and, as for practical observations, the whole of the countryside and the garden is open to you once you have received the guidance I hope to afford.

Here, then, are a few easy things you can do in connection with seeds:

Dissect some soaked "seeds" of Broad Bean, Runner Bean, Pea, Vegetable Marrow, Sycamore and Sunflower and make careful sketches of their different organs as far as you can distinguish them. (A needle will often help you in separating the parts of seeds, flowers, etc., and a good hand-lens—which is quite an inexpensive item—is almost indispensable.)

Take two sets, each of about a couple of dozen, of Runner or Broad Beans. In one set seal up the little hole referred to on p. 12 with a dab of grease or sealing-wax. Weigh both sets and put them in separate basins of water. After about two hours take them out, dry them off roughly on a piece of blotting-paper and re-weigh them. Which set do you find shows the greater relative increase in weight (through the absorption of water)?

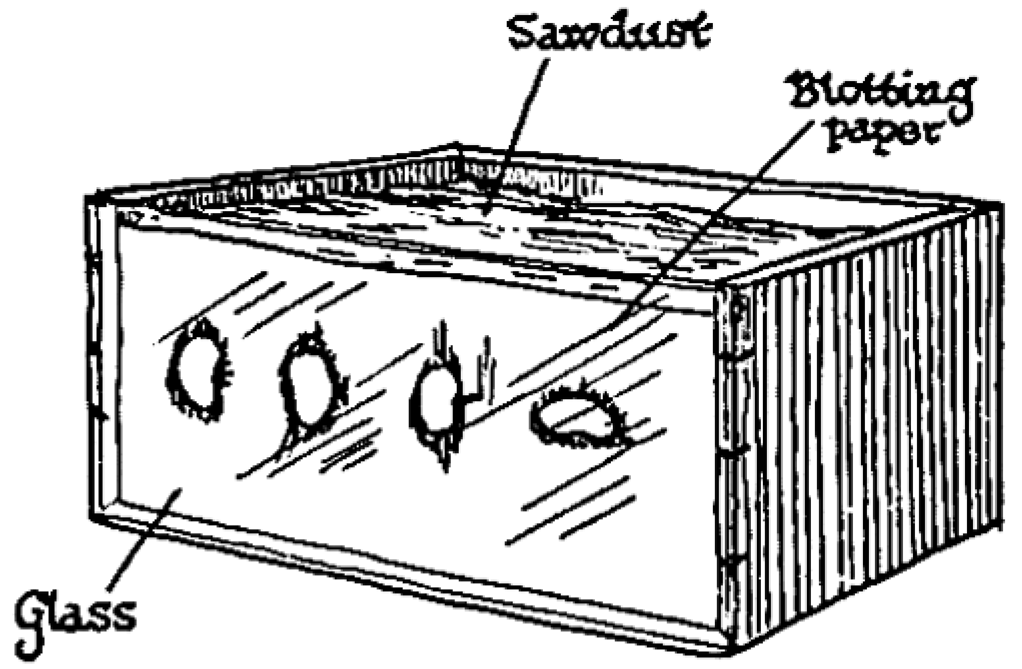
CHAPTER III

WATCHING THE SEED GROW

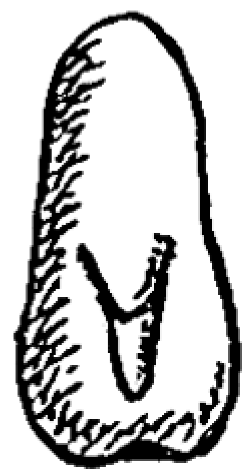
THE next thing I want to tell you about is how we issued the summons that set the seed's tiny piece of mechanism in motion. Everyone knows that it is the simplest thing in the world to make a seed grow. You just stick it in the ground, and sooner or later you see the delicate stem thrusting up through the soil and then proceeding to unfold its leaves in rather a slow and hesitating manner, as if it were not quite certain whether it had arrived at the right station. Yet, though this may seem the most ordinary thing in the world, we have only to reflect a moment and ask ourselves how it comes about to realise, perhaps with something of a shock of surprise, that we do not know the least thing about the process. It is one of those small miracles that take place a million times a day all over the world, and fail to awaken our wonder simply because they are so common. What influence is it that has spun the fly-wheel and started up an engine that, barring accidents, will henceforth see to its own fuel supply and run of itself until it runs down for good and all? Clearly we must inquire a little further if we are to discover anything of the answer to this question. Even then, I am afraid, it will be only a partial answer; for, in observing the germination of a seed, we are studying the beginning of a new life; and the beginning of all life, whether of plant or animal, remains an unsolved riddle.

Fortunately, however, there are several points on which our curiosity may be satisfied. Though we cannot discover *why* a seed responds to certain influences by beginning to grow, we can at least learn a good deal about what those influences are and how the seed reacts to them. The three things necessary to start germination are moisture, air and warmth. Water is needed to liquefy the food stored in the seed-leaves and enable it to travel to the growing points of the root and shoot. Air is required because plants, like animals, must breathe in order to live. And a certain degree of warmth is as necessary to plants as it is to ourselves, because without it the body cannot perform its various functions. The favourable temperature varies with different plants, as it does with human beings. For instance, the ideal for Wheat is about 29 degrees Centigrade, while Maize is a colder subject and prefers a temperature of about 34 degrees.

If we put a seed into the ground in ordinary spring or summer weather, Nature will provide it with all that it needs; for the temperature will be favourable and the soil contains both moisture and air. The drawback to this method, however—from our point of view, at least—is that we cannot watch what goes on. This is disappointing, but I think I can help you over the difficulty by describing some of the devices which my uncle employed. They had the effect of opening up a window below the ground, through which we could see the first stirrings of the seed as it slowly awakened to life. One device was to take a lamp-chimney, stand it in a flower-pot or bowl, and fit inside the chimney a roll of blotting-paper so that it pressed against the glass. We then got some sawdust (Sphagnum moss or soil would have done as well), filled the space inside the blotting-paper with it and also packed some round the outside of the chimney to fix it in the pot. Another plan was to use an ordinary glass tumbler, or better still a glass jug, instead of a lamp-chimney. The best method, however, was to take a box, remove one side



Box for Germinating Seeds



Broad Bean Seed

(or even two opposite sides) and tack a piece of glass in its place with a sheet of blotting-paper laid inside it, and then fill the box with the sawdust.

Afterwards we pushed a number of soaked Broad Beans down between the glass and the blotting-paper. My uncle purposely placed the seeds in different positions—some with one end up, some with another, and so on—because, he said, we should presently see them perform some interesting tricks. It only then remained for us to damp the sawdust, and our underground window was ready for operations. The water in the sawdust soaked through the blotting-paper and entered the seed through its porous coat; and, as the seed contained in its seed-leaves a store of food sufficient to tide it over the first stages of growth, it was independent of outside sources of supply.

It was during a dismal spell of rainy weather at the beginning of the Christmas holidays that we began our observations, and I can remember how thankful my long-suffering mother was that we had found an entertaining pastime to occupy us and save us from wandering moodily about the house and kicking the furniture to pieces. Uncle Fred set the seeds early one afternoon, and by the next evening two of them had burst their coats in the region of the triangular bulge, just above the little hole I told you of. Next morning we were in the study before giving a thought to breakfast. Well, there were all the beans with their skins broken in such a way that the ruptured part formed a triangular flap with the apex downwards, and we could see the roots creeping out and beginning to raise the flaps. By the following morning the roots had their pointed tips well clear of the flaps and looked like so many dogs'-tongues hanging out. I will tell you later about the behaviour of the seeds we had set in unnatural positions, and only describe now that of the one we allowed to start fair—that is, with the tip of the root pointing downwards. At the end of another three or four days (the rate of growth is greatly influenced by temperature) the root was over an inch long and seemed to be getting fluffy. I asked Uncle Fred about this, and he made me examine the "fluff" through his pocket lens. I could see then that it was a dense mass of short, silky hairs, as fine as fine as could be. They began just below the top of the root and stopped short a little above the tip. Uncle Fred explained that these "root-hairs", as they were called, were, for all their apparent insignificance, absolutely vital to the plant, and presently I will tell you why.

At this point Janet, who was always an impatient little monkey, grabbed the lens, which I had thoughtlessly put down on the table, and began screwing up her eye over it as she squinted at the seeds. Presently she said she could see a sort of shiny, semi-transparent sheath all round the tip of the root and what was that for, Uncle?

"I wondered which of you expert botanists would notice that first," said Uncle Fred. "It's the root-cap—a sort of thick skin that protects the end of the root as it bores its way through the soil."

That's another thing I mean to tell you about presently, but meantime we had both turned our attention to what was going on just above the top of the root. The flap of broken skin was by now pushed up like a projecting roof and, pressing hard against it from underneath, we could make out a faintly green object. "That," explained my uncle, "is the stem forcing its way out. At present the bud at its tip is still curved in between the seed-leaves and held there."

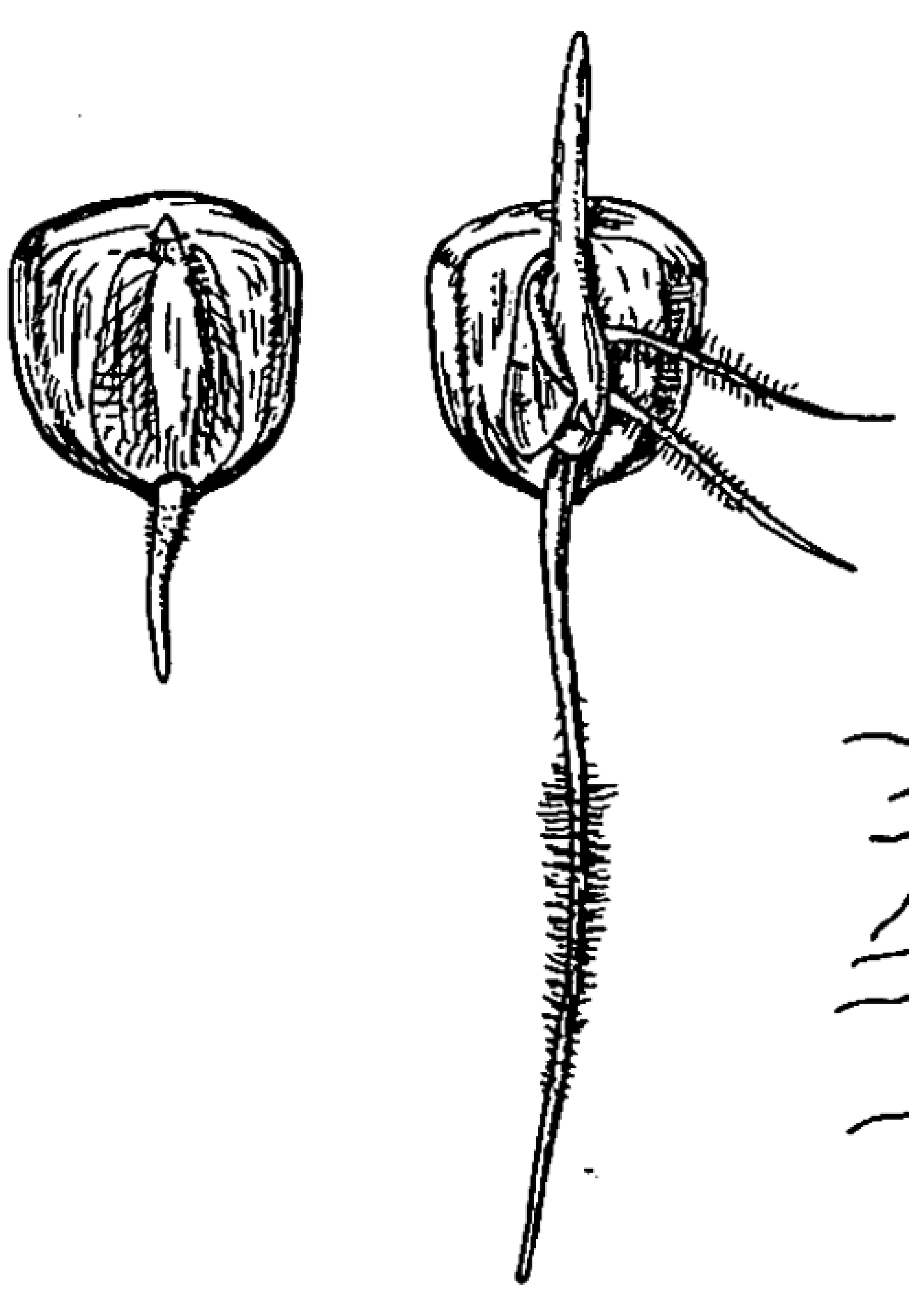
It wasn't till several days had passed that the stem stood out at all clearly between the stalks that connected it with the seed-leaves on either side. Then we saw that it was bent in a loop and Uncle Fred told us that most plants emerge from the soil in that manner, and for a very good reason. If the task of pushing up through the earth were left to the leaf-bud at the tip of the stem, that delicate organ would find itself in serious difficulties if it encountered very stiff soil or anything in the nature of a half-brick. The looped stem, on the contrary, with its smooth and rounded surface, would make light of, perhaps not a half-brick, but certainly of stiff soil or any ordinary bit of stone. It would work round the obstacle without receiving any damage, or even shoulder it out of the way, for the looped formation gives it a greater thrusting power.

Meanwhile the root had grown to about three inches in length and was putting out side roots. These grew quite quickly, and very soon they followed the example of the main or tap root by clothing themselves with root-hairs.

As time went on the stem succeeded in getting its head clear of the flap. We saw the mass of the crumpled leaf-bud emerge; then the fat little stem slowly straightened out its bend; the leaves expanded; and there was our seedling, complete with a main root, an assemblage of side roots, a stem and leaves, all developed from the seemingly lifeless seed with no outside help but that of a supply of water, air and warmth. The first foliage-leaves were small and quite different in shape from the bigger ones which came later, and my uncle told us that these differences are a feature of many plants.

If you want to study the later history of the Broad Bean, it is best to observe young plants grown from seeds sown in beds, pulling them up one by one to examine them at the different stages of their growth. You will then see how the stem continues to lengthen, producing foliage-leaves as it grows, and how the root goes on burrowing down and multiplying its branch roots in all directions. The seed-leaves, which have provided the supplies for the early stages of growth, shrivel up as their contents are withdrawn by the vigorous infant and finally disappear. Their work is finished, and henceforth the plant will provide for itself. Very many plants, however, make a further use of their seed-leaves. They bring them up above ground, where they turn green and set to work to make fresh supplies of food like the foliage-leaves—a subject for us to explore when we come to study the special work of leaves. We watched this being done by sowing "seeds" of French Beans, Sunflowers, Sycamores and Beeches, and most interesting it was to follow their different habits of taking up the business of life.

We also germinated some grains of Maize, by the simple method of laying them on soaked blotting-paper and covering them with a glass jar. We wanted to see if monocotyledons behaved in the same way as dicotyledons, and quickly discovered that they did not. The first root did not develop into a good stout root like that of the Broad Bean, but remained thin and slender. Furthermore, it was quickly followed by a pair of similar roots which sprouted from near the base of the stem. Others followed later, till there was quite a bunch of long, slender roots, all set with root-hairs and protected by a root-cap. This irregular arrangement of slender or fibrous roots, all of about the same thickness, is a feature of seedlings with only one seed-leaf; while the system we saw in the Broad Bean, showing a thickened main or tap root from which the later roots branched, is found fairly generally in seedlings with two seed-leaves.



Germination of a Grain of Maize

The shoot of the Maize, too, showed that it had its own way of progressing in the new world it was discovering around it. At first the young leaves were enclosed in a sheath that stood up like a thin, pointed pencil and formed an admirable spike for thrusting up through the soil. The leaves within were rolled up, one inside the other, in an upright tube and, once they had burst out of the sheath, they shot up and opened out their grass-like blades one by one in regular order.

Now I think we have talked enough about seeds and seedlings. Presently I will give you some experiments to do, and then we will pass on to the study of the different parts of plants in general—roots, stems, leaves, flowers and fruits—taking them each in turn and seeking out the mysteries of their growth. In this way we shall discover the marvellous efficiency with which each of these separate members of the plant contributes to the harmonious working of the whole. We shall learn, too, how the complex mechanism of the plant, hidden for the present from our eyes, enlists in its service, not only the air and sunlight of the heavens and the water and chemical foods of the earth, but also the winged insects and roving animals who visit it in its quiet station. For in this royal manner does the humblest herb levy its toll upon all the elements that enter upon its little corner of the great teeming world of life. Which reminds me that some of Janet's verses relate to this very attitude of the plant.

Said the King, " I alone am the lord of the land."
" Dear me! " said the plant. " Is that so? "
" Why, of course," glared the King; " don't you see, I command
All the people—and *they* ought to know."

" You command all the people? Indeed! " smiled the plant.
" Well, I don't like to say it's not true;
But I frequently make them serve *me* when I want."
" Oh, indeed! " gasped the King. " Oh, you *do*? "

" I'm afraid that I do—though you'll not think it's nice—
And I summon the birds from the blue,
And the four-legged sheep and the squirrels and mice.
Does Your Majesty govern them too? "

" Well, I really don't know," snapped the King in a huff,
" I must seek my Lord Chancellor's views.
But you certainly raid my dominions enough—
Is there anything else that you use? "

" Well, the wind is my servant—that's very well known;
And the rivers I hardly could spare;
And of course all the food in the soil is my own,
Not forgetting the food in the air."

" By my solid gold Crown and my Sceptre and Sword,"
Cried the King, " this is treason indeed!
I shall tell the Lord Chancellor every word."
And he scurried away at full speed.

If you'd like to know whether the plant spoke true,
And how she established her reign,
You must patiently read for a chapter or two
And the answer, I hope, will be plain.

Now for the experiments I promised:

Sow a few soaked seeds in a flower-pot of soil and keep them watered. Sow some dry ones in another pot of dry soil and do not water them. Keep both pots in a warm place. The seeds in the first one will germinate, but not the others. This shows that water is necessary for the germination of seeds.

Put some White Mustard seeds in a basinful of water. Place some others on wet blotting-paper, lay them in a tobacco tin lined at the bottom with saturated cotton-wool and close the tin to prevent the moisture from evaporating. In a day or so (if you have kept the seeds in a warm room) most of the seeds in the tin will have germinated. Those under water, however, will have made very little, if any, progress, the reason being that the water has separated them from the air. This shows that air is necessary for germination.

You can easily prove that a certain degree of warmth is necessary for germinating seeds by sowing seeds of the same kind in pots and standing the latter in different temperatures—*e.g.*, one in a warm room, one in a chilly place out of doors and so on.

Chief Librarian

CHAPTER IV

EXPLORING UNDERGROUND

Roots are not attractive-looking objects. They seem to be nothing but a formless muddle. They may even excite in us something of the distaste (but also something of the wonder) we feel for worms and grubs and other creatures that lurk unnaturally in the darkness of the soil. Yet, once you understand the work performed by these grubby organs, I think you will find them as interesting as the more wholesome-looking parts of the plant that appear above ground.

Before we settle down to talk about that, however, I must just tell you of a quaint old superstition that used to be held about a certain root. The plant concerned was the Mandrake, which grows in southern Europe. The popular tale said that it flourished only under the gibbet where a murderer had been hanged—but you can form your own opinion about that. The plant has a thick root, which often forks like a carrot. This suggested to fanciful minds the form of a man's legs, and a little careful pruning gave the root quite a passable likeness to the complete figure of a little man. The Mandrake was believed to have mysterious powers of healing and to possess certain other supernatural advantages, including the extremely valuable ones of bringing its possessor good luck and foretelling the future. Hence it was much sought after by the sick and the unfortunate. Unhappily, however, there was a serious drawback in connection with gathering it. When you tried to pull it up from the ground it let out a succession of blood-curdling screams, and whoever heard the screams would go mad or die. That, of course, made people chary of handling the herb, till presently someone hit on the bright idea of tying a dog to it and, after stopping up his own ears with wax, running back till he was out of hearing of the expected shrieks. Then he called to the dog, the dog tried to obey and, in so doing, tugged the root out of the ground. It is true that the faithful dog lost his reason, or his life, but its unnatural owner secured the coveted root. When the English herb-sellers found the true Mandrake-root too expensive to import from abroad they used the "rootstock" of our native White Bryony instead, and drove a thriving, but dishonest, trade in the substitute. In some countries the people cherished their Mandrake-mannikins as amongst their most valuable treasures, dressing them up like dolls and preserving them with the utmost care.

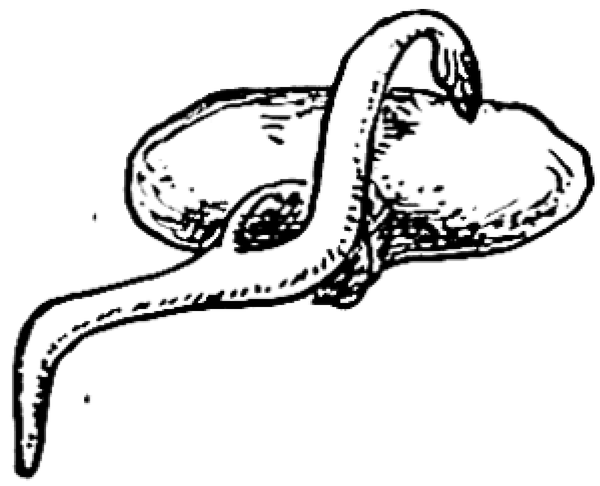
The best way to begin our study of the root is to ask ourselves what the organ is for: in other words, what are its functions? Once we learn this, we shall begin to understand why it is constructed as it is and also how its construction helps it to carry out its own special duties.

The principal duties of the root are: first, to anchor the plant to the ground so that it shall not be torn up by the wind or any other violent enemy (such as a gardener heartlessly weeding); and, secondly, to absorb water from the soil, together with certain chemical elements which are generally found there and which the plant needs as one part of its food-supply.

Roots, as you know, have the habit, which Janet found so baffling, of growing down into the soil, and, in the Bean seedling which I described, the main root made a bee-line for the bottom of the germinating-box. You will remember that, along with the particular seed whose activities we followed, my uncle set several other seeds in different positions. One of these seeds was set with the root lying horizontally—that is, with the tip pointing towards the side of the box instead of towards the base. Another one was placed completely upside down, the root-tip pointing towards the top of the box. Remembering that it is natural for roots to grow downwards, we were eager to see how these roots would deal with the puzzling situation in which an unkind fate had placed them. Well, they proved quite equal to the occasion, and in three days had overcome the problem we had so tantalisingly set them. The root of the first seed grew out horizontally until it reached the end of the seed, and then, having won clear of that obstruction, turned contentedly downwards along its natural course. In the other seed, where the root found itself pointing up forlornly into the air, that organ promptly started to loop the loop. The tip bent over towards the glass side of the box and vigorously grew in a downward curve until, having completed a semi-circle of growth, it found itself, like its companion, heading happily for the bottom of the box.

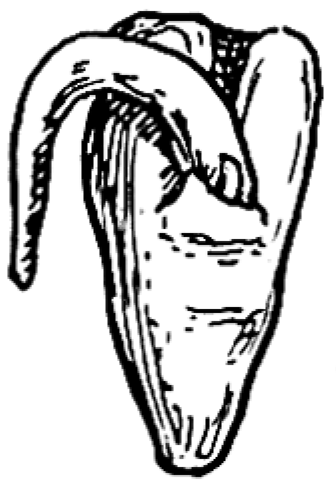
Now, at first sight it does not seem at all remarkable that roots should grow downwards, for it appears to us to be nothing but their natural habit to do so. Yet, when you realise, as you may from the instances I have given, the obstacles they will overcome in pursuing that habit, it does make you wonder what compelling force there is behind it all. Well, I can give you a partial solution of the mystery. You know what happens if you chance to stroll over the edge of your roof. You descend at high speed in a straight line to the solid earth below. This is in obedience to a mysterious law of Nature, called gravity, which tends to draw all objects towards the centre of the earth. It is this law that brings its influence to bear on the main root of a plant, causing it to grow towards the earth's centre and making it twist and turn in every conceivable manner in order to achieve that object.

A



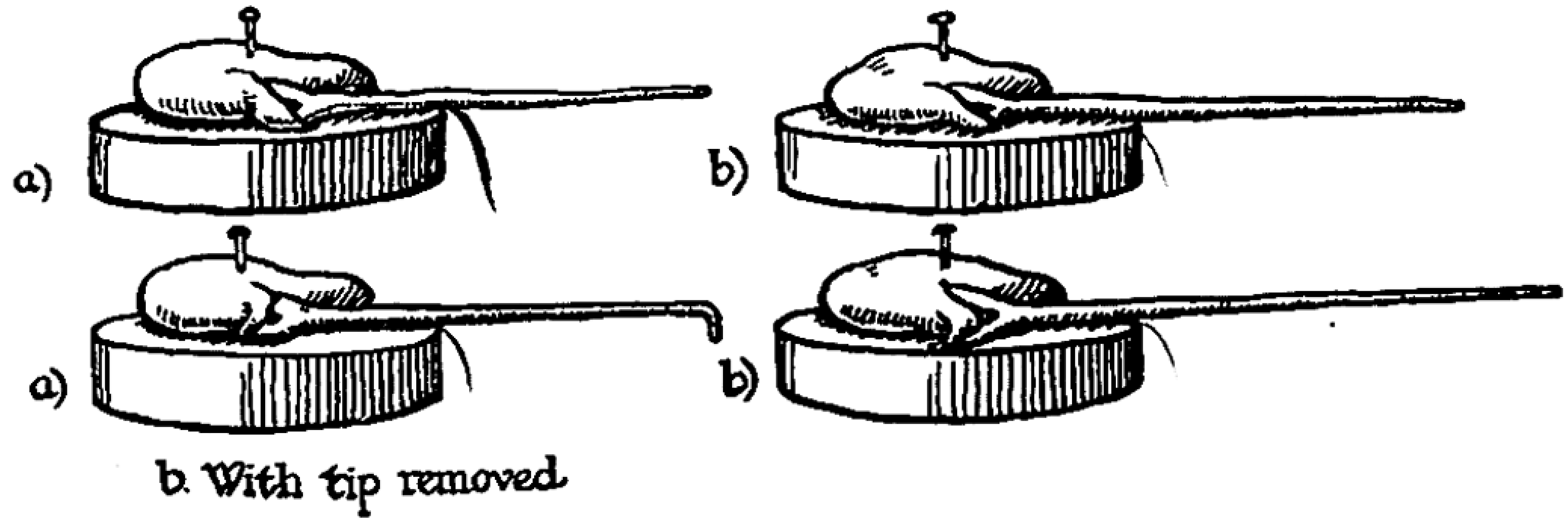
A. The Broad Bean Seed we set Horizontally

B



B. The One we placed Upside Down

One step farther we can go, and I will describe it in connection with some further experiments which my uncle made. He took two Broad Bean seedlings with roots about two inches long and, sticking a pin heartlessly through each fleshy body, fastened it to a cork so that the stiff root lay in a horizontal position with half of its length projecting over the edge. Then, to our surprise, he cut off the tip of one of the roots. After that he placed the corks in a dish containing some water and covered them with a jar. Then, bearing in mind that roots naturally grow in the darkness of the soil, he put the whole collection in a dark cupboard and left it there till the next day. The result, when we examined it, was not quite what Janet and I had expected. We thought we should find that the roots had bent downwards where they passed over the edges of the corks, but it was not so. The root which had *not* had its tip chopped off had indeed bent, but only at a point a little way behind the tip; while the other root—the one which had been deprived of its tip—had not bent at all. Now, the whole of a root is, of course, subject to the universal law of gravity, but the experiment seemed to show that the tip is specially sensitive to its directing influence and thus responsible for the root's downward habit of growth; and this actually appears to be the case.



Broad Bean Seedlings on Corks

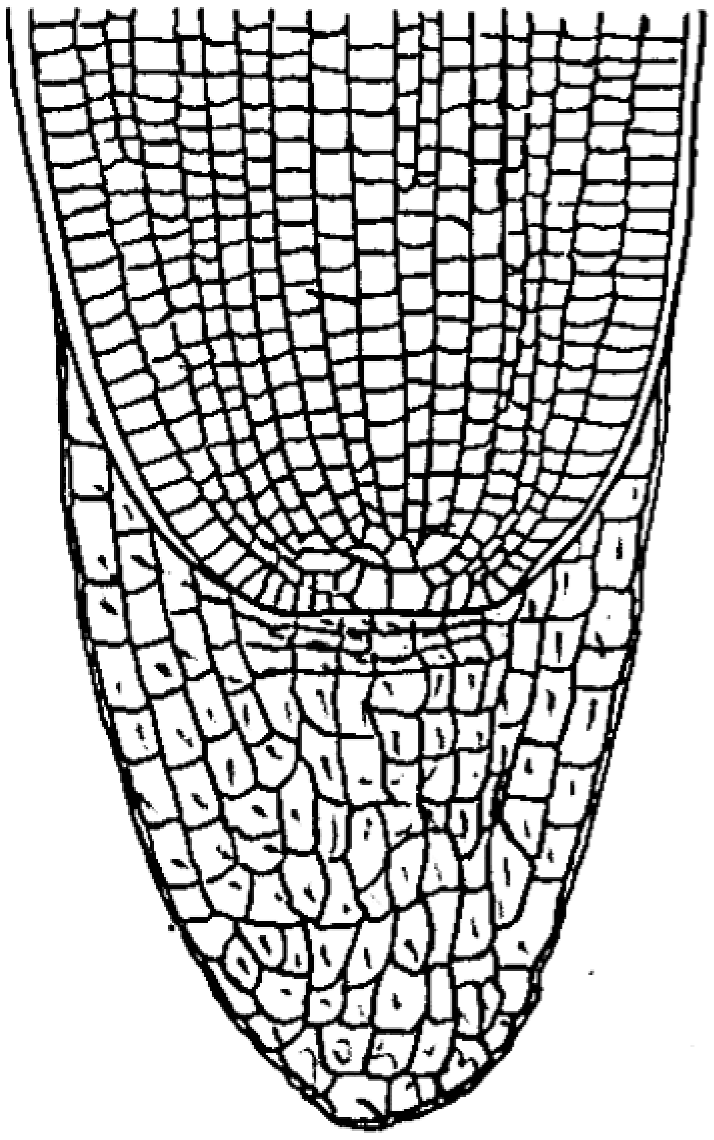
Curiously enough, the side roots given off by the main root do not behave at all in the same way as their parent. Their direction is, indeed, affected by gravity, but other forces seem to influence them as well. Janet said it was as if Mr. Gravity was sternly commanding them to grow straight downwards like their parent, while Mr. Somebody-Else was shouting out to them to take a totally different course, until the poor things, trying to obey both traffic-directors, lost their heads and ran about all over the place. Actually it isn't quite like that. The side roots slope downwards and outwards from the main root at a fairly regular angle; but the lesser roots that branch from these grow out in all directions.

A very little thought will show how this diverse behaviour of the main and branch roots helps the plant. As the main root bores more and more deeply into the earth, and the side roots multiply and lengthen and themselves give off rootlets which spread in all directions, the whole system not only strengthens its grip on the soil, but constantly taps fresh sources of water and nourishment.

There are certain other factors which cause roots to disobey the commands of the tyrant gravity, the most striking of them being the moisture in the soil. Roots, and more especially their smaller branches, seem to have an uncanny power of " smelling out " the water which the plant needs, and their tips will depart from their original course and grow out in a new direction in search of it. They will go even farther than this. One day my uncle knocked the bottom out of a box and replaced it with wire gauze. He then filled the box with wet moss and, sowing some Cress seeds in it, hung it up in a sloping position in a dry room. In due time we saw the roots pushing through the meshes of the gauze and beginning to grow down into the air. Then, to our astonishment, they gradually turned and grew back into the moss. They were dissatisfied with the dry air, and preferred the moister region of the moss, where they could find the water that was essential to the plant's growth. Gravity, they seemed to think, was all very well as a guide so long as it proved of service, but, when it led them into desert places, it was time to assert their independence. This marked sensitiveness to the presence of water is another striking instance of how admirably the roots are adapted for the work they have to do.

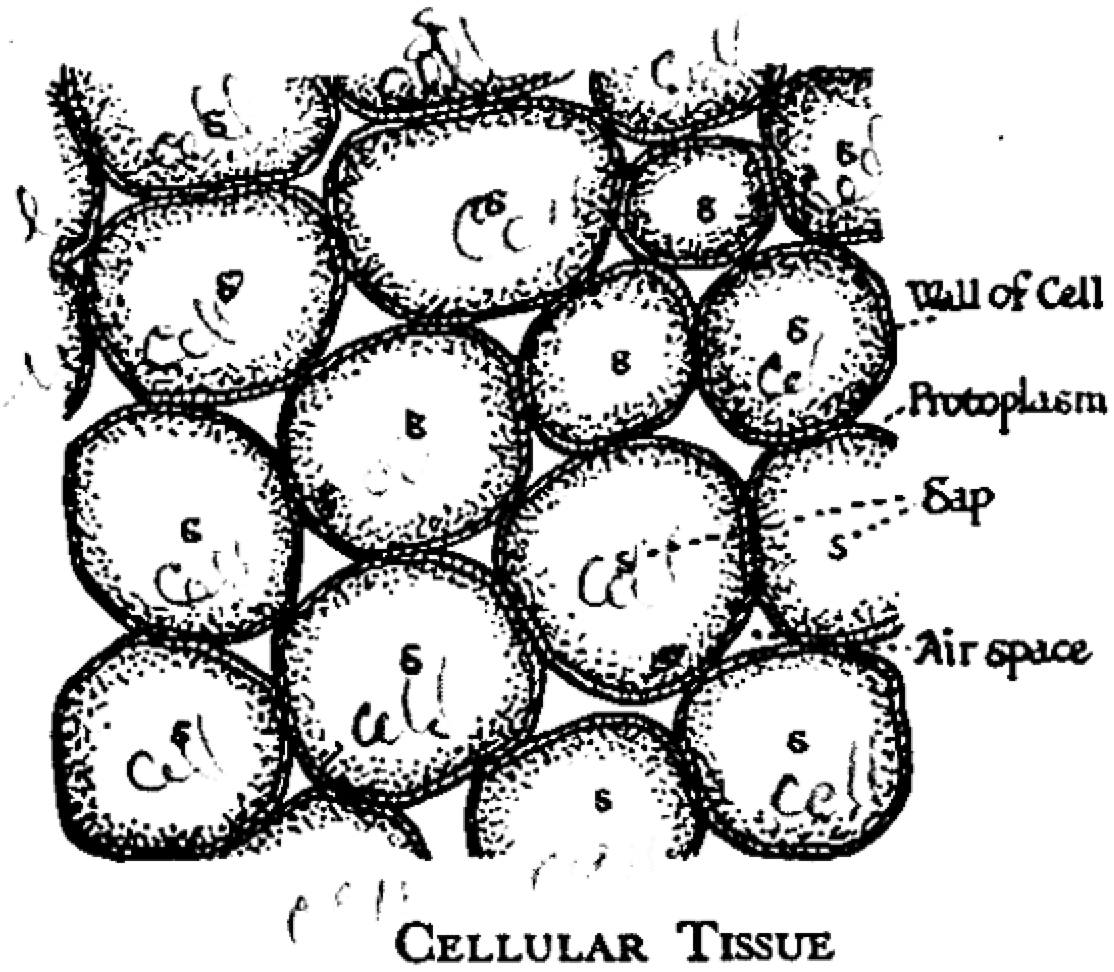
Now let us see if we can discover something of how a root is made and of the actual mechanism of its growth.

To begin with I must explain that plants are made up of anything up to millions of " cells ". You may get some idea of their appearance in the mass by thinking of a sponge or a piece of honeycomb, though their shapes, and the material of which they are made, are far more varied and in the main they are very much smaller. They are usually so small indeed that you need a lens or a microscope to distinguish them. A painstaking botanist has calculated that, if a man undertook the impossible task of counting the cells in a large forest-tree, from the ground upwards, he would only get as high as a foot or so if he counted night and day and lived to twice the age of Methuselah, which the Bible tells us was 969 years. By that time his reckoning would amount to something like 200,000,000,000 cells! * The cells of a plant are packed more or less closely together so as to make a compact body of "tissues", yet most of them have minute air-spaces between their walls. These cells are exceedingly complicated units, and a great deal too difficult for us to study at this stage. All I need tell you about them at present is that, in the general body of the plant, each living cell is filled with the rich sap that is its life-blood, and that it is lined with a mysterious semi-fluid substance called "protoplasm". Protoplasm is the essential living matter in both plants and animals—the substance that makes them "alive" and capable of taking



THE TIP OF A ROOT

The small cells above are the growing point; the larger cells at the bottom the root cap.



CELLULAR TISSUE

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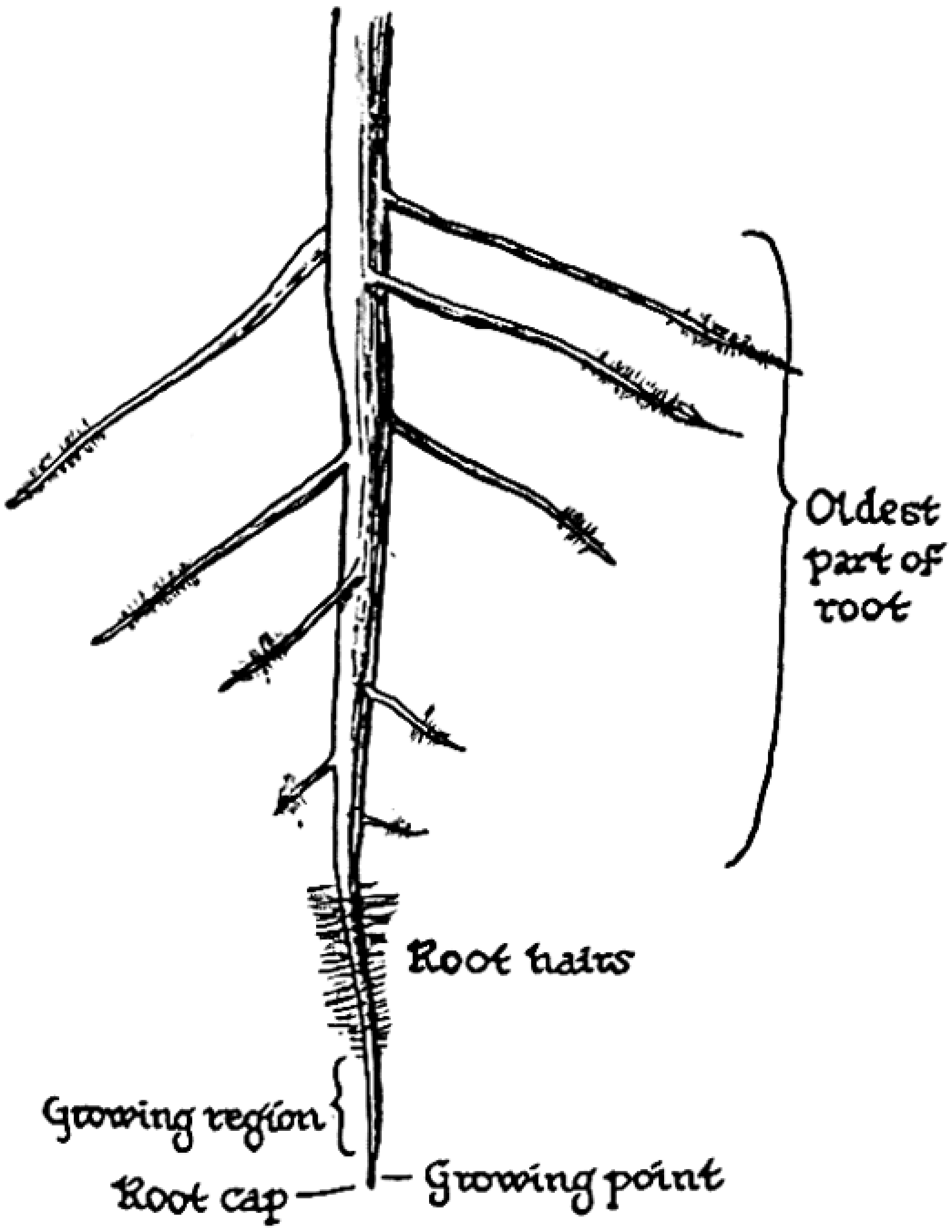
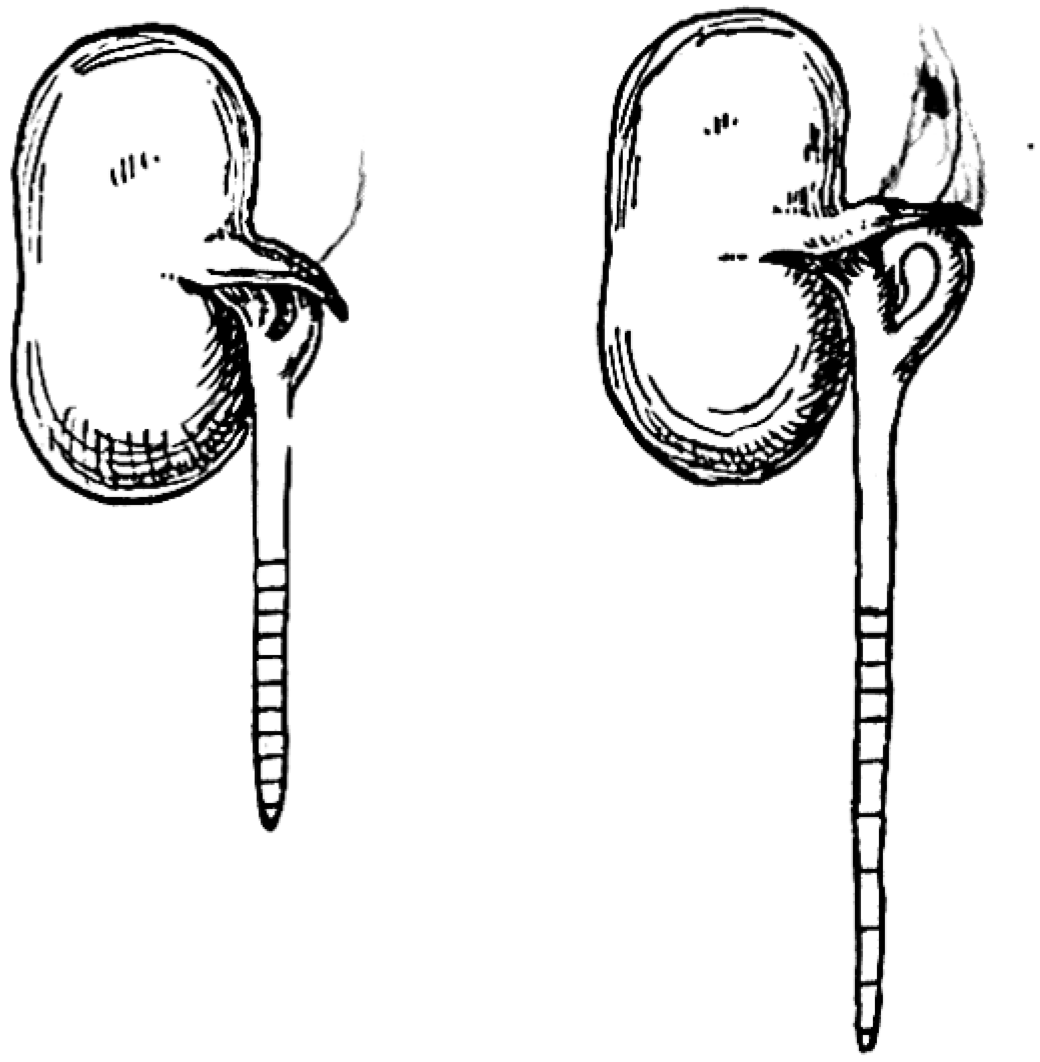
* See Professor Seward's *Plants: What They Are and What They Do.*

in their food, breathing, moving, growing and reproducing their kind. When we speak of " cells " in connection with the activities of a plant, we really mean the vital protoplasm which they contain.

Let us start by examining the lower end of a young Broad Bean root, where the root-cap is situated. Uncle Fred, as you will remember, had already explained that this was like a piece of thick skin serving to protect the growing root as it burrowed into the soil. He now showed us that it fitted over the tip of the root like a thimble.



ROOT OF BROAD BEAN



ROOT OF BROAD BEAN SEEDLING, SHOWING INCREASE IN LENGTHENING, OR GROWING, REGION.

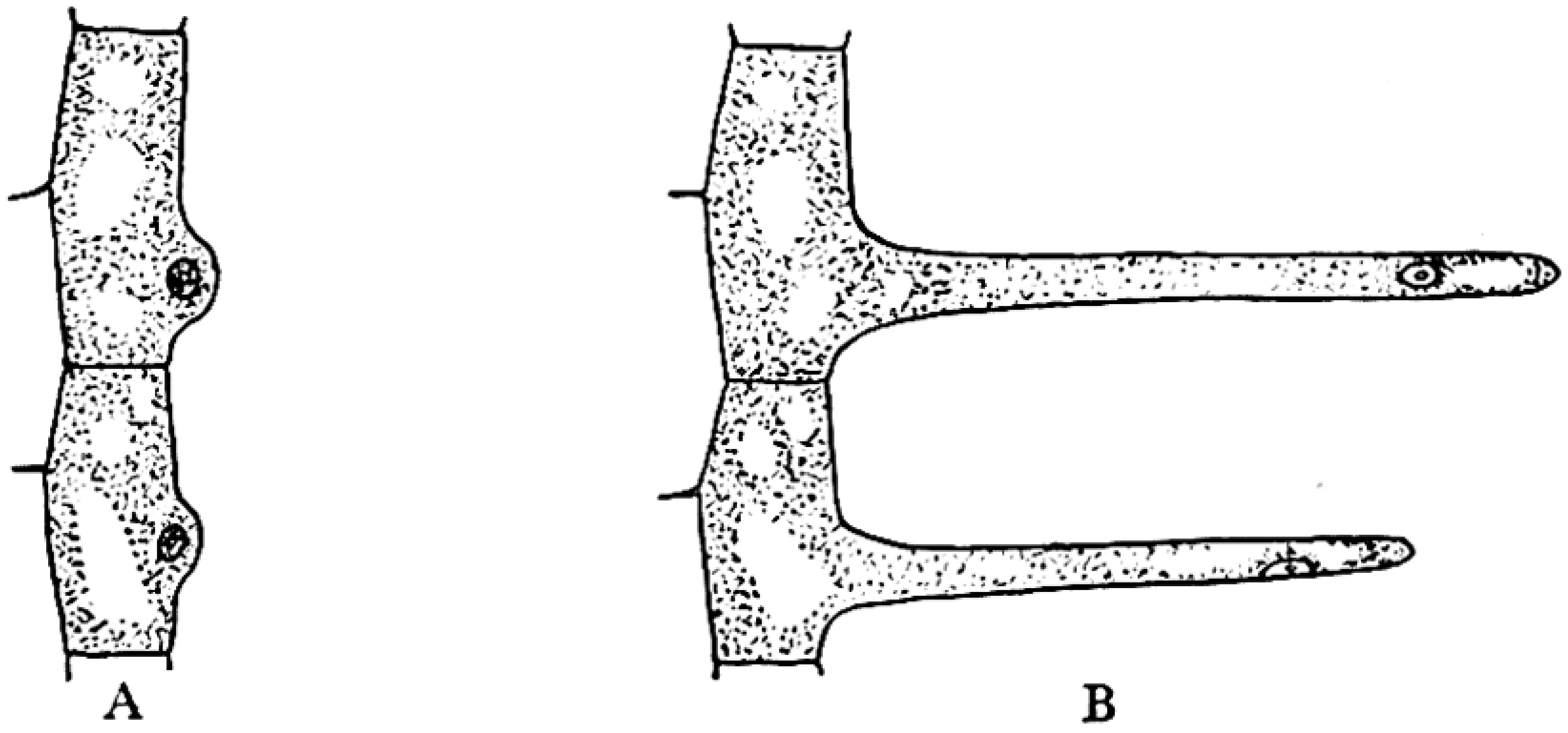
This tip is composed of a small colony of cells of such supreme importance to the plant that they thoroughly deserve the special protection which the root-cap affords them. They are the cells which cause the root to grow in length, for which reason they are called the growing point. They are in a constant state of activity, each cell dividing, growing again, and again dividing, and so continually creating new cells. Some of the new cells go to thicken the root-cap from within, and so make good the wear and tear from without which it suffers during its progress through the soil. The greater part of the new cells, however, are added to the root *above* the growing point, where they rapidly increase in size. It is here mainly that, as a result of this increase, the root lengthens, for which reason we may call it the lengthening region. The growing point produces all the cells that go to increase the length of the main root. The root is constantly creeping down through the soil, its growing point tirelessly piling up new cells which enlarge in the lengthening region above. Its action, indeed, is rather like that of a steamer with its following wake. The prow of the vessel stands for the root-cap, the engines represent the active growing point and the lengthening wake is the lengthening region of the root.

It is quite easy to make a root demonstrate the position of its lengthening region. You take a seedling with a root an inch or so long and, commencing at the tip, mark little lines on its surface with Indian ink, setting the lines $\frac{1}{16}$ of an inch apart. After forty-eight hours or so you will discover that, while the lines at the tip, *and also those towards the top*, remain much the same, the lines in the short region between the growing point and the beginning of the root-hairs have become more or less widely separated. This shows that it is in this short region that the principal growth in length has occurred.

We now come to that part of the root where the root-hairs appear. As the root creeps down, the root-hairs follow up close above the lengthening region. At the same time they are dying off at their higher end, and thus the length of root which they cover—usually anything up to an inch or two—always remains about the same. Above the region of the root-hairs is the highest and oldest portion of the root. Here the root thickens and the side roots branch out. These side roots start from the central core of the main root, and I regret to say that they are cannibals. They literally eat their way out to the surface, for they devour the cells that lie in their path in order to nourish their own bodies.

We have thus discovered five parts of the root showing distinctive features: (1) the root-cap, (2) the growing point, (3) the main lengthening region where most of the new cells are packed, (4) the region covered by the root-hairs and (5) the oldest part that increases in thickness and bears side roots.

Now let me tell you something about the internal construction of a root, and at the same time explain how the organ helps the plant with its commissariat. The entire root is covered by a skin and, as we have seen, the part which lies just above the lengthening region is set with a numerous mass of very fine root-hairs. The plant, as I mentioned earlier, needs for its nourishment certain chemicals called mineral salts. We need the same kind of nourishment ourselves, though, unlike the plant, we cannot draw it direct from the earth, but have to have it made up for us, as helpless babies have their food prepared for them by their mothers. The mineral salts are found in the soil dissolved in the soil-water. Each of the root-hairs is really a single long, hollow cell growing out from the skin of the root. Its walls are very thin and delicate, and they give free passage to the water and dissolved mineral salts.



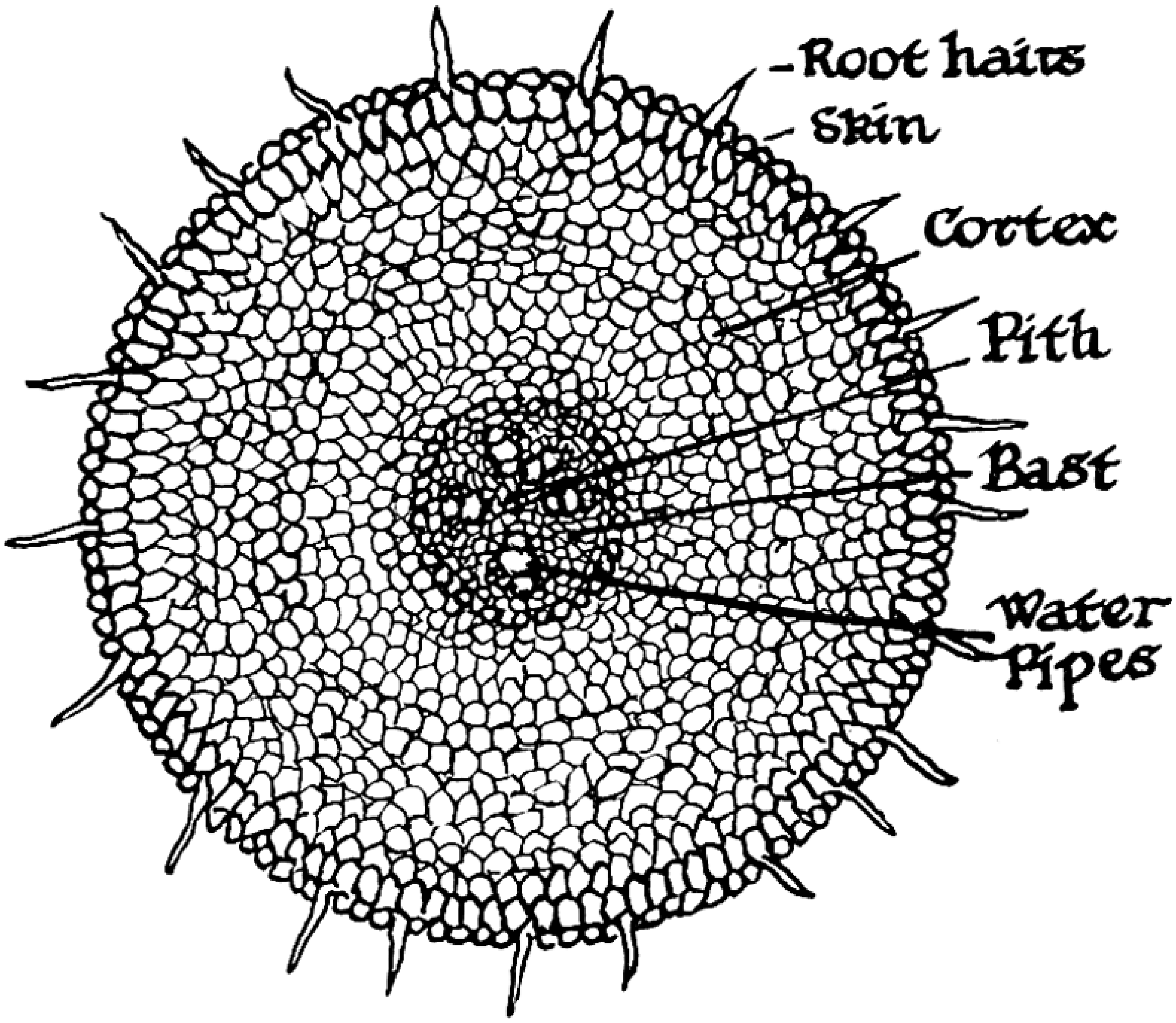
ROOT-HAIRS
A. Beginning B. Extended

The root-hairs absorb this solution (the " rising sap " as it is often called) and pass it on to the cells of the " cortex ". The cortex consists of several layers of cells lying beneath the skin. The solution streams from layer to layer towards the centre of the root, the root-hairs constantly taking in fresh supplies and sustaining the flow. The innermost cells of the cortex surround the central portion of the root. That central portion contains a number of hard strands gathered together in separate " bundles ". The bundles usually number from two to about eight in dicotyledons, and they are arranged (where their number makes this possible, of course) more or less in a ring. They are the "wood" of the root, and form its hardest part. The most prominent feature of the wood is a number of long, hollow strands or vessels which serve as water-pipes. They run up the whole length of the root, continue through the stem and branch off into the leaves and flowers. The innermost cells of the cortex, having become swollen with the sap received from the root-hairs, pass on the liquid into the water-pipes; and these conduct it up into the stem until it reaches the leaves. The leaves use it in making up the food of the plant, as we shall see presently. Meanwhile, the cells of the cortex, which have delivered the sap to the water-pipes, are replenished with fresh supplies received from the root-hairs, and these supplies are once more discharged into the water-pipes. So the work goes on throughout the life of the plant, the root-hairs absorbing fresh supplies from the soil as fast as they are drawn off into the water-pipes.

In the spaces between the wood-bundles are some other bundles of a more delicate character called the "bast". The bast-bundles are not directly concerned with the part of the root's operations I have described. Their principal work begins when the liquid food has been made up by the leaves. The bast contains some tubes, called sieve-tubes, which, like the water-pipes of the wood-bundles, run right up the root, stem, etc., and it is through these that a great part of the food-stream is carried back from the leaves and distributed through the plant.

The drawing on p. 36 will help to make clear these rather complex internal parts. It is a diagram of what you would see if you cut a root across in the region of the root-hairs and looked down on one of the cut ends—your eyes having first been miraculously endowed with the magnifying power of a strong lens or of a microscope. Around the outside is a single layer of cells forming the skin, with a number of root-hairs extending from them. Within it are the layers of cells forming the cortex. Then come the wood- and bast-bundles, as they appear, you will bear in mind, when cut across. It is interesting to look at these from another direction. Slit a root lengthways and you can pick some of them out with a pin as so many long strands. The mass of cells lying in the very centre of the root is called the "pith". Side roots are made up in the same way as the main root, and their water-pipes and sieve-tubes are connected up with those of the main root, just as the water-pipes of your house are connected up with the main in the street.

You must often have wondered how the sap of a plant succeeds in *flowing upwards* so as to reach the top of the stem; or, if you have not, you are unlike the many botanists who have puzzled their heads over such unnatural behaviour. The feat is all the more surprising when you reflect that it occurs in the tallest trees, which of course are some hundreds of feet high. We are still uncertain how the trick is done, though the action of the root goes some way towards explaining it. When you think of the thousands of cells in the cortex of the root and its numerous rootlets, all passing on their contents into the water-pipes and keeping up the operation day and night, you can appreciate that they must often exercise quite a considerable force.

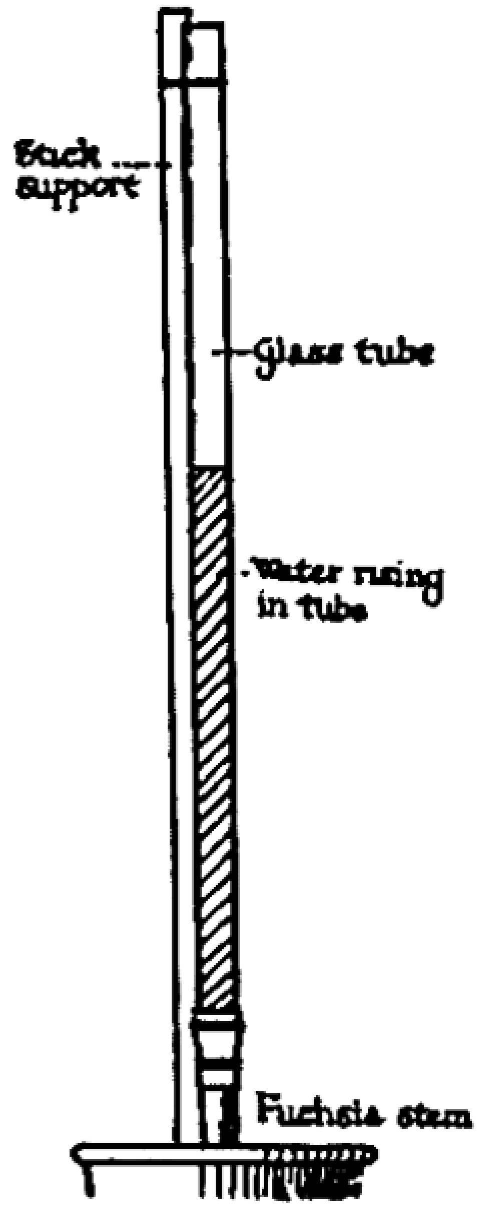


Transverse Section of Root

You can judge this force on occasion by noticing how a tree "bleeds" at the stump if it is felled in springtime, when the roots are working actively, or how shrubs and other plants similarly bleed if they are pruned at that season. Certain tests which have been made by botanists bring the lesson home even more forcibly. If you were to cut down the stem of a Fuchsia plant growing in well-watered soil, and then fit over the stump a long glass tube containing a little water, you would see the column of water lengthen in the tube till it reached a height of perhaps seven or eight feet. That would mean that the root was forcing soil-water up through the stump and into the tube. Normally, of course, the water would travel up the water-pipes in the stem of the plant. The glass tube in this case represents the stem and enables us to judge the force exerted by the root.

Actually, there is another, and probably far stronger, force working from the leaves. These are constantly evaporating the water they receive, and they discharge such large quantities of the vapour that they exert a strong "pull" on the column of water rising to them through the stem.

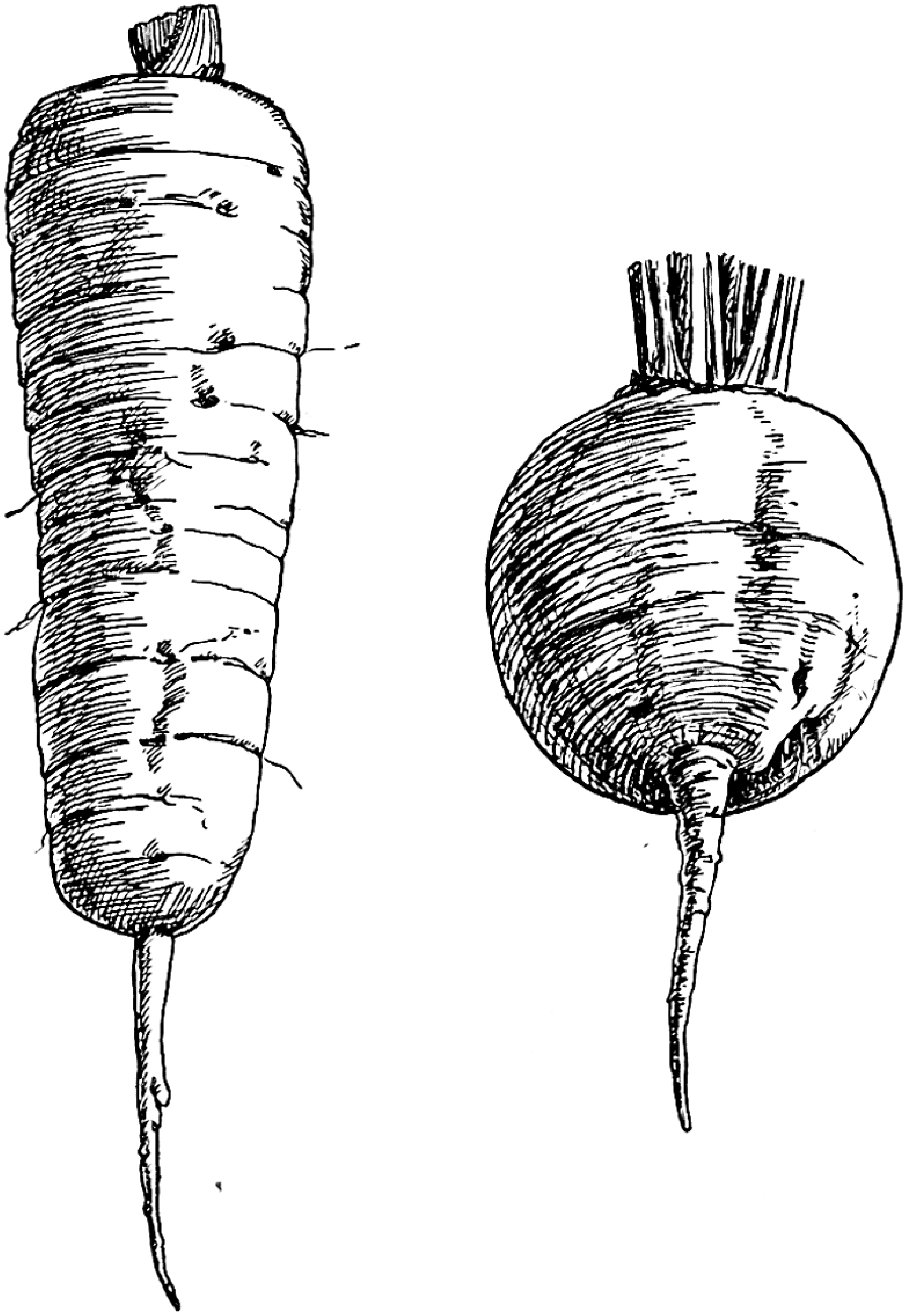
These two forces—the root-pressure from below and the "pull", or suction, of the leaves from above—with other forces that are too technical to describe, all help to cause that upward flow of the sap which seems to us to defy the law of gravity. Yet their explanation of the problem is not completely satisfactory, and so, as I have said before, we are still left in some uncertainty.



DEMONSTRATION OF ROOT-PRESSURE

I must say a further word about the bundles of the root before we pass on. There are usually some additional hard strands, and frequently quite tough fibres, associated with them; and all these hard tissues, placed as they are in long, continuous lines towards (often actually in) the centre of the root, form a core of strengthening material that serves to keep the root rigid and helps it to resist the tugging force of high winds that might otherwise tear up the plant bodily from the soil.

As a root ages it becomes more or less thickened with the growth of new wood and bast. In annuals (plants, such as a great number of our common wild flowers, that complete their growth within a single year and then die) the thickening is not great. In perennials (plants that last for several years), however, especially trees (which are only extra big plants), it is often very considerable. As the process continues, the older parts of the root lose their original skin, and this is replaced by layers of cork, or even by a thick bark, as a new protective coat more suitable to the plant's age and girth. Other important changes



Carrots and Beet swollen with Food-reserve occur in the arrangement of the wood and bast, but these are rather too complex to describe. I shall, however, tell you a lot more about the growth and development of such tissues when we talk about the stem.

The fibrous roots of monocotyledons do not go on getting thicker and thicker in the way I have mentioned, and the bundles are generally much more numerous than those of dicotyledons.

The roots of biennial plants (those that take two years to complete their growth and then die) often serve a special purpose. During the first year the plant produces leaves which make a great deal more food than is required for that season's growth. The surplus is stored up in the roots, and these become greatly swollen in consequence. During the second year the plant draws on this reserve to produce flowers and " seeds ", and so complete its growth. The carrots, parsnips and beet which we cook and eat are chiefly the tap roots of those plants enormously enlarged in this way. That they are, in fact, tap roots is shown by the little side roots you find arranged on them in regular rows.

There is a tremendous amount of variety in the growth and construction of the roots of different kinds of plants and of all roots at the different stages of their lives. What I have told you is only a bare general outline of the subject, but it is quite enough for you to remember at the moment, and anyhow Janet is pestering me to give you some more of her rhymes.

A root is a curious thing—
It's as hard to define as a noun.
  It drinks through the hairs
  That its overcoat bears
And the water goes up and not down!

It carries its cap on its toe,
As if that would help it to walk!
  And, when its first flabby
  Young coat gets too shabby,
It puts on a new one of cork.

Mr. Gravity makes it grow *down*
(Though it turns when there's water to sup):
  Thus, although I am told
  It may grow very old,
Yet, in ageing, it never *grows up!*

Now a word about experiments:

In carrying out the experiment described on p. 37 you should cut down the stem of the Fuchsia (a Geranium or a Vegetable Marrow would do) so that a stump of about two inches, free of branches, remains. Fit a short piece of rubber tubing (previously wetted) over this and bind the joint firmly with fine wire. Fill the tube with water and then fit into it a glass tube, say two or three feet long (you can obtain one from the chemist), again wiring the joint tightly. You will need to support the glass tube by tying it to a stick stuck in the soil. Then keep the plant well watered and watch the liquid rise in the glass tube, measuring it from time to time with a ruler. Spring is the best season for this experiment, as the root-pressure is then at its greatest.

Germinate some Cress seeds by laying them on soaked flannel (which you must keep moist) and observe the prolific crop of root-hairs.

Take a Broad Bean root that has grown side roots; slice it through downwards and observe how the side roots start from the centre of the main root.

Pull up Broad Bean, Dandelion, Grass and other plants. Study their different root systems and make drawings.

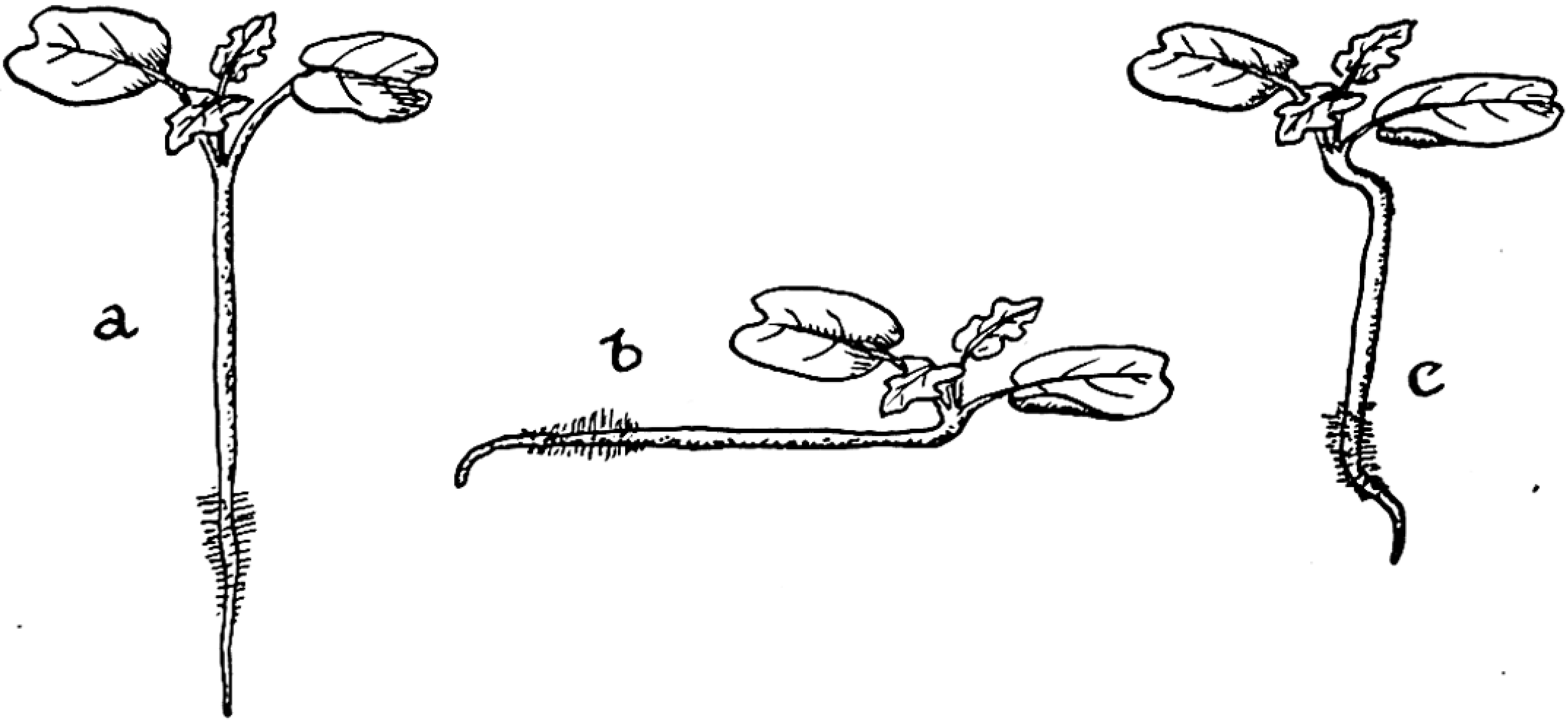
CHAPTER V

THE HUMBLE SERVANT

COMING up above ground again, the next member of the plant to stand forward for our examination is the stem. We may begin putting it through its paces by asking it the same question that we addressed to the root: What are its functions? Well, the stem plays a less active part in the operations of the plant than the other members; and, in fact, some plants practically do without one. The roots, as we have seen, are importers of food-materials and controllers of the water-supply. The leaves, as we shall see presently, are importers of another kind of food-material and also the factories where the materials are made up. The flowers produce seeds. The seeds produce new plants. Amid this display of industrious activity the stem finds its uses limited in the main to the drudgery of two functions. It has to display the leaves and flowers to the light and air so that those organs may efficiently perform their labours; and it has to serve as a channel for conducting water and mineral salts from the root to the leaves and for distributing the manufactured food throughout the plant. It is true that it is permitted to share to some extent in the work of the leaves, but its principal and distinctive duties are the two I have mentioned. (Janet says that, so far as she is concerned, its "principal and distinctive duties" are to provide girls with candy and boys with pipes, as the Garden Angelica does; but that is merely being frivolous.)

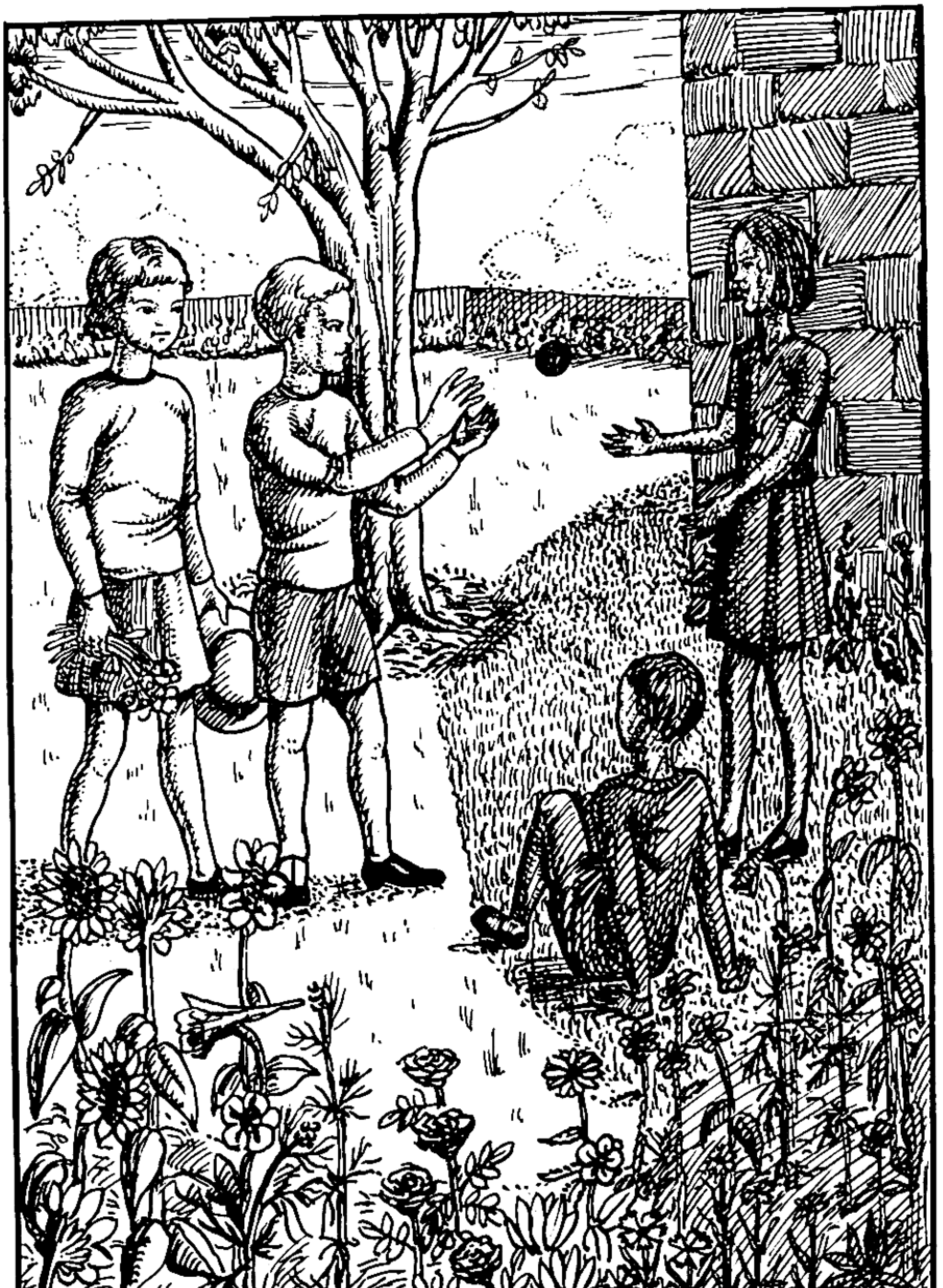
Let us examine this humble Cinderella of the plant's household and discover how it performs its duties. Everyone knows that it is the common habit of main stems to grow upwards. In the Broad Bean seeds we germinated, the stems (though the actual tops were at first bent in a loop) followed that practice no matter how we placed the seed. Just as the roots persisted in seeking a downward course, so the stems sought an upward one. One day we took a seedling growing in a pot of earth and laid the pot on its side in a dark cupboard, the stem, of course, lying in a horizontal position. When we took it out again two days later the stem had bent upwards in a right angle a little way behind the tip. We stood the pot upright so that the bent top of the stem was once more lying horizontally and again left it in the cupboard. Thereupon it made another right angle and once more pointed serenely upwards.

The cause of this decided behaviour is the same in root and stem, only, for reasons which are not at present fully known, it has opposite effects on the two organs. The plant as a whole, in common with all other objects, is subject to the downward " pull " of gravity; but at the same time gravity exerts a *guiding* influence over the growing stem, as it does over the growing root. It causes the tip of the stem to point constantly upwards and the tip of the root constantly downwards. The branches of the stem, like those of the root, are less influenced by gravity, and grow out, as we know from observation, in various directions.



Demonstration of Effect of Gravity on Stem

Gravity does not by any means have things all its own way with stems, any more than it does with roots. You must often have noticed how the stems of plants placed near a window bend over towards the light. They are more sensitive to light than to gravity, and so they become bent out of the course which gravity laid down for them.



THE ROBUST CHILD AND THE LANKY CHILD

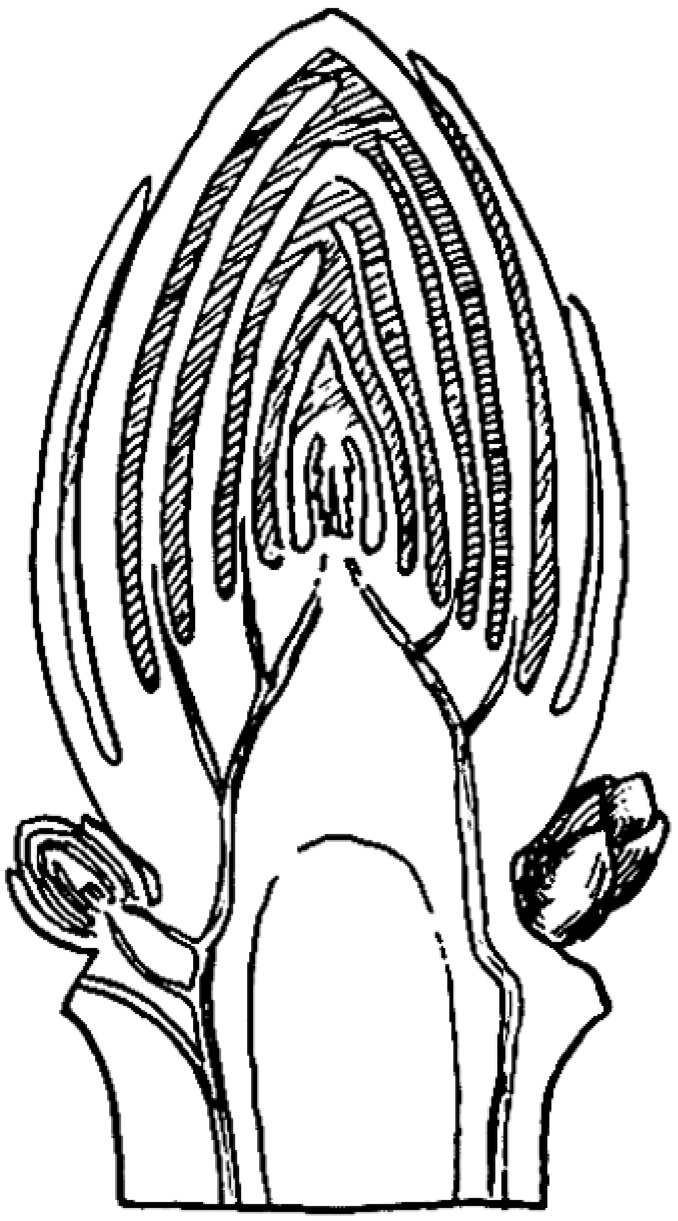
There are good reasons for the stem's responses to the influences of gravity and light. We have seen that one of the principal duties of the stem is to display the leaves to the light and air. A plant needs these elements even more than we do. It needs abundant light because its leaves can only manufacture food in sufficient quantities if their surfaces are well illuminated. It is to indulge in this sun-bathing that plants set by a window bend over towards the brighter light entering there; and I should add that growing leaves themselves are sensitive to light and bend or twist in such a way as to bring their surfaces into the most favourable position for receiving illumination. Next, the plant needs air for breathing and other purposes; and, as I shall show you soon, the leaves are its principal breathing-organs as well as its food-factories.

Imagine a seed germinating in the soil. It has but a limited reserve of food stored up in its seed-leaves and, as for air, it finds that none too satisfactory. Unless the stem can reach the light and air of the heavens and get its leaves working before the food-reserve gives out, the plant must perish. Gravity comes to its aid by directing it in the shortest way up—a straight line. Another point is this: Stems grown in darkness or dim light lengthen rapidly as they struggle to reach the brighter illumination they need; but their growth is " weedy ". Anyone can appreciate this by a glance at plants growing in a dim corner of the garden. (Devonshire people say of a tall and lanky child that " he has grawed up in a loo corner "—meaning a dim, sheltered corner.) On the other hand, stems grown in a good light lengthen more slowly and make a sturdier growth. These effects help the seedling in this way: in the darkness of the soil the stem lengthens rapidly and, guided by gravity, reaches the light and air without any perilous dawdling on the way. Once up above the soil the stem turns towards the brightest light (if the illumination around it is unequal), as we saw in the case of the window-plants, and, growing more slowly now that it has found its element, produces firmer tissues.

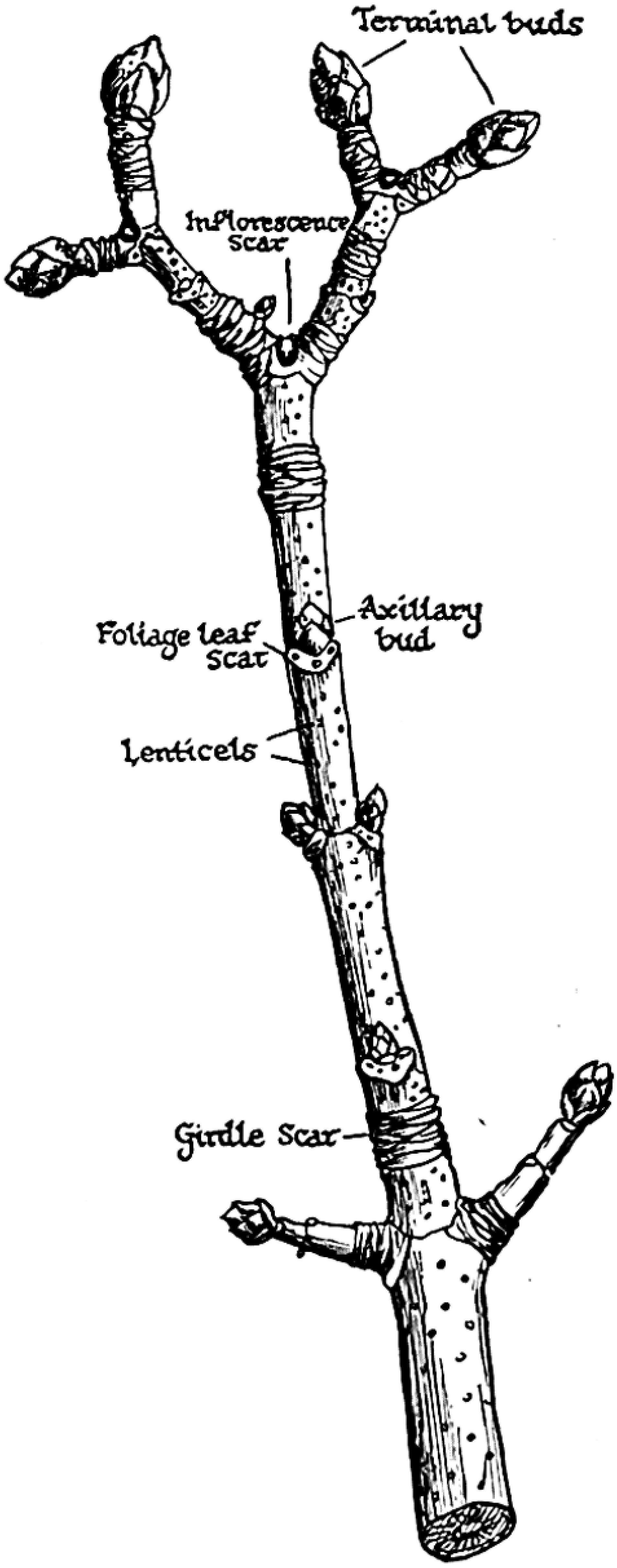
We know from our study of the Broad Bean seedling that a stem has a bud at its tip. The bud consists of a number of tender young leaves folded closely together around the tip. The tip itself is the growing point of the stem, corresponding with the growing point of the root, and it is here that the cells, by constantly dividing and forming new cells, cause the stem to increase in length. The tip does not need any protective organ such as the root-cap, because, as we have seen, the stem usually pushes up through the soil in a loop and, after that of course, barring accidents, it will meet with no more friction. The tip does, however, receive some measure of protection from the leaves of the bud, because they closely overlap it. Below the growing point is the lengthening region, as in the root, only in the stem it is usually much longer. Below the lengthening region we come to the older part of the stem, which has ceased to grow longer, but gets thicker and may produce branches.

Now let us return to the bud, for it is deserving of a little further attention. The tiny leaves of which it is composed are crowded so closely together that you cannot detect the little spaces of stem between them; but they are there all the same. As the stem grows in length the spaces lengthen out and the leaves are left behind at regular intervals, fresh leaves being formed at the tip in their place.

The growing point of a stem may continue to make new cells throughout the life of the plant, in which case it is responsible for the stem's entire growth in length. There is nothing in this to arouse our wonder when the plant is a small one; but it becomes simply staggering when you reflect that it may be equally true of a lofty tree. I remember so well how my Uncle Fred impressed this astonishing fact upon our minds. We were staying at his house in the country at the time, and he took us out into the garden and pulled up at the trunk of a fine old Fir tree swaying slowly in the wind.


VERTICAL SECTION OF A LEAF-BUD, SHOWING ALSO TWO SIDE BUDS

"Take a good look at it," he said. "It's tall enough, isn't it?—eighty feet, I should think. Yet all that height—not the thickness, mind you—was directly and entirely produced by the little colony of cells forming the growing point when it was a seedling far smaller than those Bean plants we were growing. Just think of it! Donkeys years ago the stem was so short and so fragile that a baby could have crushed it by wriggling its toes on it. It escaped that fate and all the other dangers that surround young natural growths, and the busy little colony at the tip went on dividing and multiplying themselves till their number passed clean out of the longest multiplication table ever invented as an instrument of torture for schoolchildren."



Branching of Sycamore

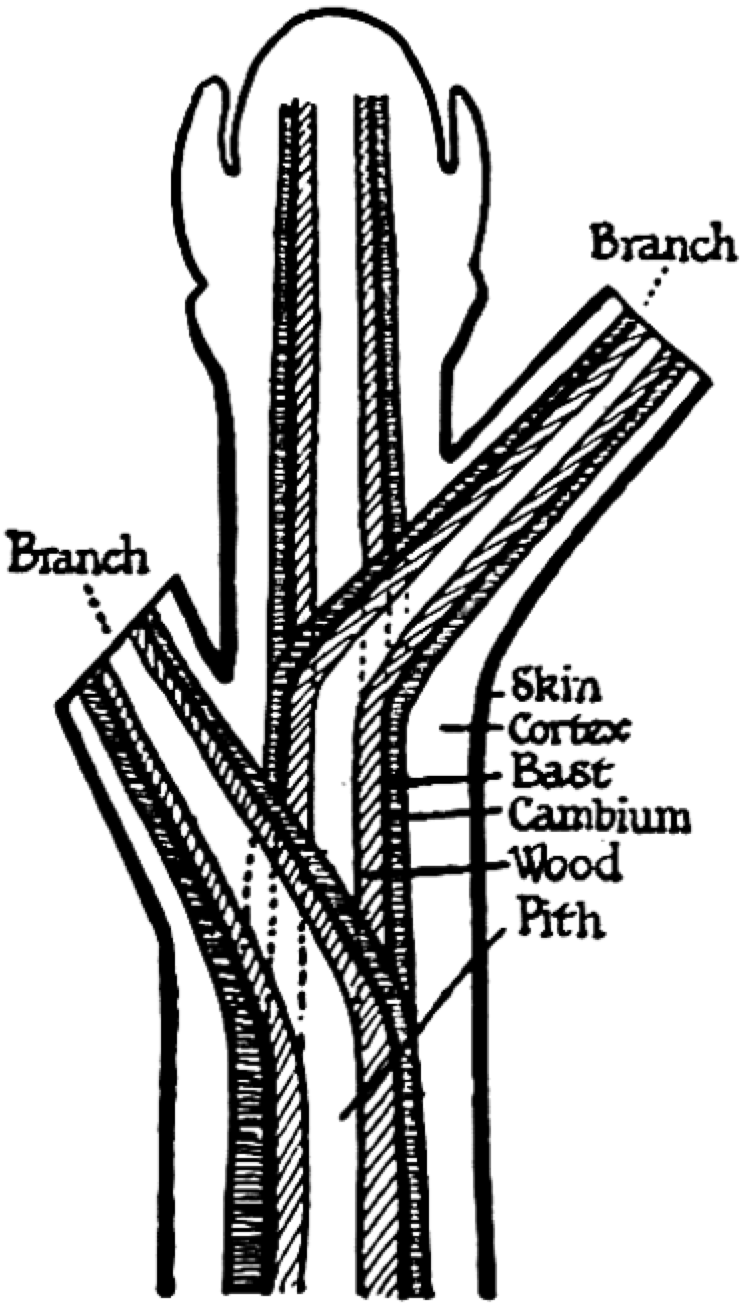
Here Janet darted a look at me and began to giggle, for arithmetic was always my weak point. My uncle went on with a knowing smile.

"And so it went on year after year until, in time, the new growth carried the stem right up into the air out of reach, and out of danger, of man and the other animals. Don't imagine that it always happens like that, though —far from it. Mostly, the cells give up after a certain height has been reached and hand over the work of further increase to a near-by branch, or the trunk may split up into a number of branches and the original shoot, or 'leader', get lost. But, in cases like our Fir tree there, the cells that started the work on the ground-level will see it through to the end up in the sky."

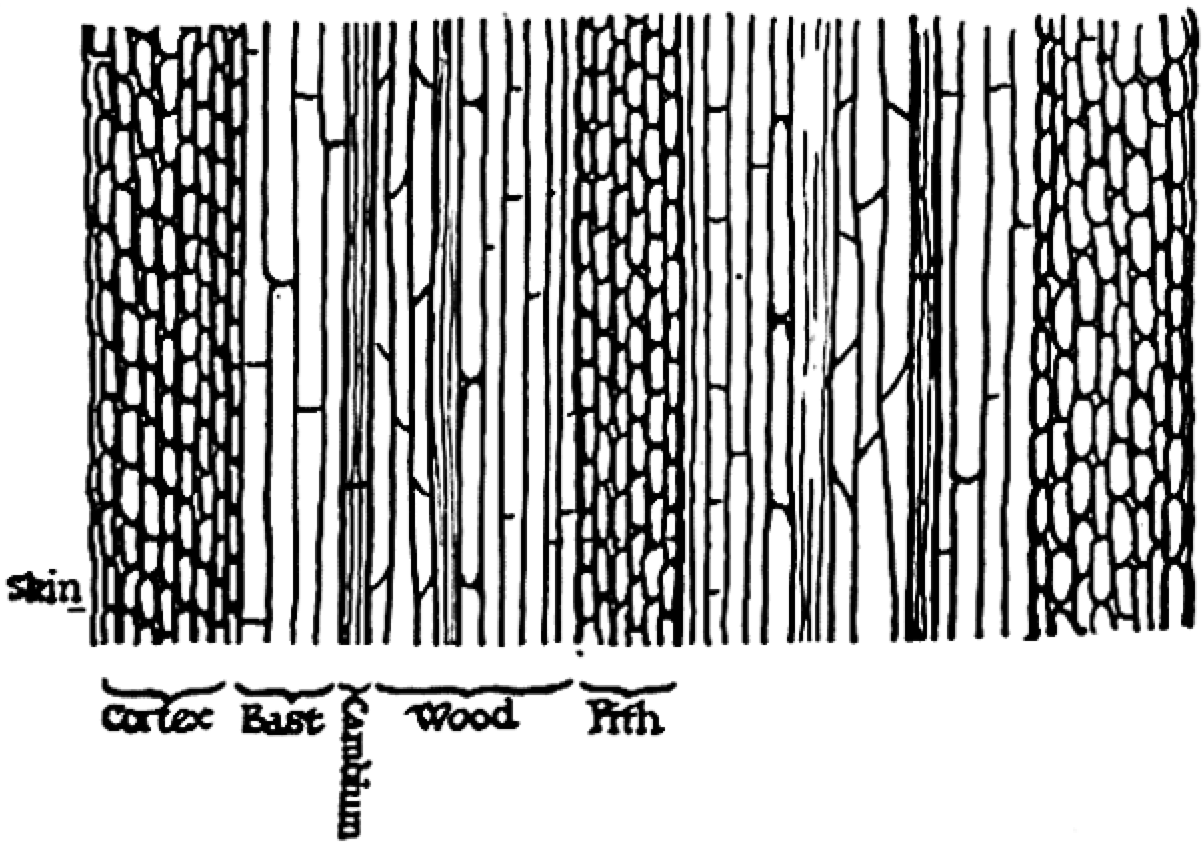
Now a word about how a stem branches. You have seen the leaves of the bud being spaced out at regular intervals. If, when the plant has grown somewhat, you look in the angle formed by each leaf with the stem from which it grows, you will usually find a side bud there. Many, though by no means all, of these side buds will lengthen out into branches, and the branches will bear leaves that have been spaced out from their own bud, just as the main stem bears leaves that have been spaced out from *its* bud. The branches themselves will produce buds at the bases of each of *their* leaves, and these in turn may develop into smaller branches, and so on. It is in this way that the regular branch-system of a plant is produced, and you can study it in its fullest development in trees.

Sometimes buds are produced out of their regular order. You see this when a Willow tree is pollarded—that is, has its top or main branches lopped off. It seems as though this drastic treatment acts as a stimulus to certain of the neighbouring cells. A crisis has arisen in their lives, and the time has come for them to drop their everyday work of passing on sap and such-like drudgery. They begin to build up little mounds of new cells which stand out around the top of the trunk as buds, and soon these, together with other buds which seem never to have wakened up since they were first formed, develop into an irregular crop of slender branches to make up for the stout ones they have lost. This, of course, supplies the answer to that question—about King Charles' head and the trees being able to make up for having their heads chopped off—which Janet fired off at me when she first began bothering about the strange ways of plants; only, of course, I didn't know it then.

In many perennial plants, such as trees and shrubs, the buds formed later in the season do not open that year, but wait till the following spring. When we see the leaves of trees bursting open in springtime we are apt to assume that they have only just been formed. This, however, is not the case. The buds from which they spring were formed during the previous summer so that they should be all ready to expand and start their work of food-making directly the weather became safe for them. Meantime, like a provident parent, the tree has surrounded the delicate growths with lavish devices to protect them against the frost and snow, the rain and boisterous gales that the winter will bring. There are thick outer scales, often closely overlapping like the tiles of a roof, then perhaps more scales within, and often a blanket of downy hair within these. The scales, too, are sometimes painted over with a kind of varnish to make them waterproof, as anyone may see in the fat and sticky buds of the Horse Chestnut. Then, too, the position in which the buds are produced affords quite a measure of protection, the angle formed by the stem and the leaf making a snug little cradle during the bud's infancy. Some plants go further than this in the exercise of their care. The Ivy secretes its buds in a sheath at the base of the leaf-stalk, and it is only when you pull the stalk down that you discover the sleeping infant at all. The Plane tree does even better. Look for the buds in summer and you won't find them. If you are curious you will wonder why the bases of the leaf-stalks are so swollen. Pull off a leaf and—hey presto!—a bud appears in view. The leaf-stalk was hollow and the bud housed inside it more snugly than a snail in its shell.



LONGITUDINAL SECTION OF STEM



A SMALL PORTION OF THE SAME GREATLY ENLARGED.

Stems are made up of pretty much the same " tissues " as those we saw in the root. There are, however, some important differences in their arrangement and development; and, as moreover they are easier to study in stems than in roots, we will give them a little fuller attention.

We can take any typical young green stem (*e.g.*, that of a Sunflower) for examination. We glance first at the outer skin, or epidermis as it is called, which consists of a single layer of cells. Inside is the cortex. It is made up largely of soft, juicy cells, but very often the outer layers have their cell-walls thickened, and a number of tough strands or fibres often appear in different places, to help to support the stem. The cells of both epidermis and cortex, and also those of the central pith, further strengthen the stem by keeping it taut, and they do it in this way: The layers of soft, inner, juicy cells, being swollen with sap, tend to expand. The epidermis, on the other hand, resists the pressure thus exerted. The result is that the two kinds of cells, straining against each other, produce the effect that you get when you blow up a bladder or sausage-balloon. When the bladder is empty it is limp. Fill it with air, and it becomes taut and firm. So it is with a stem, the sap behaving in the same way as the air in the bladder. When a plant wilts, it is because there is not sufficient sap in its soft cells to keep them in a swollen condition.

One of the most unexpected things we learned about plants was the astonishing proportion of water they contained. Uncle Fred made some fascinating tests to demonstrate this. He took various entire green plants, and at another time different parts of plants, weighed them, dried them slowly in the bottom of the kitchen oven (when Cook was out) until the water had been driven off in steam and then re-weighed the shrivelled remains. As a matter of fact our first attempt had a rather disastrous ending. We put the pile of herbs in the bottom of the oven with the door ajar so that they should not burn and then left them. Some time later Cook returned and made some scones for tea. She made up a fierce fire, placed the scones on the top shelf of the oven and closed the door. The oven being in a dark corner of the kitchen, and Cook being rather short-sighted, she didn't notice our little contribution. But, if her sight was defective, her sense of smell was not, and presently a strange and pungent odour sent her flying to the oven. She opened the door, and a cloud of odorous smoke and steam assailed her nostrils.

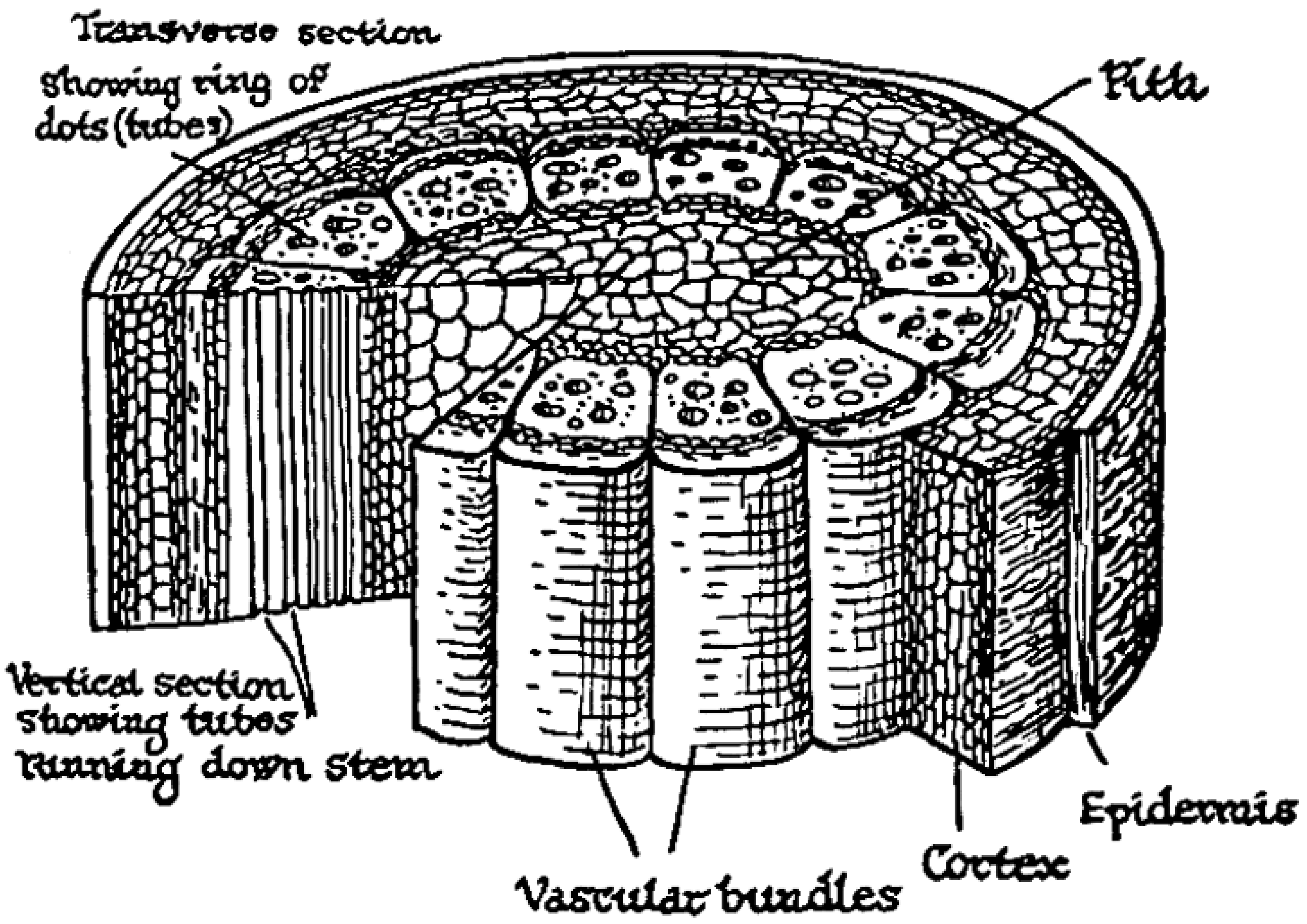
" My scones! " she wailed.

But it wasn't her scones, it was the herbs, which had caught fire. They were giving out a good, robust smell like a witches' brew, and the kitchen soon became full of it. Really the scones weren't burnt at all; but Cook indignantly declared that, even so, they would taste of them disgustin' 'erbs, and she wasn't going to send out tainted food from *her* kitchen. So we had no hot buttered scones for tea that day.

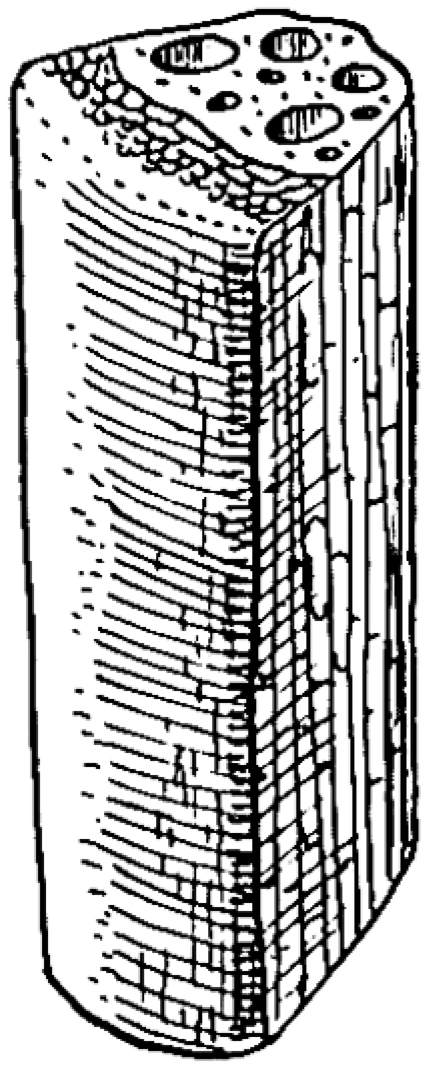
However, our later experiments, made on Cook's afternoon off, were more successful. We learned, on re-weighing the baked remains of different lots of herbs, that the woody parts had owed about half their original weight to water, and the softer parts, such as the leaves, three-quarters. Some fleshy stonecrops proved to have been (so far as weight was concerned) no less than nine-tenths water and only one-tenth solid tissues and other contents.

The cortex usually occupies a smaller proportion of a young stem than it does of a root, and the central part (consisting of the pith and the wood- and bast-bundles) is correspondingly larger. In many plants the pith disappears and the stem is hollow. In the root, you may recollect, we noticed two things about the bundles. First, the wood-bundles were separate from the bast-bundles. Secondly, the bundles were placed well towards the centre of the root to form a strengthening core. In the stem all this is changed. The bundles, in their course upwards from root to stem, have been given a twist round so that bast and wood are brought together and each bundle now comprises some bast on its outer side (*i.e.*, nearest to the epidermis of the stem) and some wood on its inner side. Furthermore, these united bundles are placed farther away from the centre of the stem, and so nearer to the epidermis, where they form a ring with a space between each bundle.

I daresay that, by now, you have come to expect plants to have good and sufficient reasons for all their mysterious little ways. The explanation of the changed position of the bundles in the stem is not at first clear. Indeed, it only becomes clear when you learn certain facts which builders and engineers have to study. We saw that the kind of strain which a root had to guard against was a *tugging* strain, tending to pull the root out of the ground—the sort of tug, in fact, that the dentist gives to your tooth. The best way for the root to resist such a strain is for it to mass its tough materials towards the centre and its more delicate tissues on the outside. This is exactly what it does, the bundles forming a central core, with the softer cells of the cortex outside them. The situation of the stem, standing as it does above the ground, is quite different. The strain, such as that caused by a gale of wind, instead of exerting a tug from above, now tends to bend the stem sideways, and it may make its onslaught from any point of the compass. Builders using upright girders know well that, in such a case, the strongest materials must be placed on the outside, where the strain is greatest, and they fashion their girders accordingly. So does the plant: it arranges its hard bundles, and also the thick-walled cells and fibres which we saw


Transverse section showing ring of dots (tubes)
Pith
Vertical section showing tubes running down stem
Epidermis
Cortex
Vascular bundles

DIAGRAMMATIC SECTION OF A STEM, SHOWING WATER PIPES (TUBES), WITH CAMBIUM AND BAST OUTSIDE THEM



A SECTION OF A STEM, SHOWING A SINGLE BUNDLE WITH WATER PIPES, CAMBIUM AND BAST in the cortex, as near to the outside of its stem as it can conveniently manage.

It will give you an idea of how tough the supporting fibres of plants can be if I tell you of the commercial uses to which some of them are put. The fibres of the cultivated Flax, a plant only two or three feet high, are stripped from the stems, spun into thread and then woven into linen. The New Zealand Flax contains fibres strong enough to be made into ropes and baskets. In the early days, before machinery was introduced into the country, the Maoris used to strip them laboriously by hand. They were woven into cloth or plaited into baskets and also used for making fishing-lines and bird-snares and for binding together the parts of their primitive stone implements. The fibres of the Hemp, which is rather like a stinging Nettle, only larger, also serve for making ropes, besides being used in the sails of ships. Jute, the fibres of an Indian plant, form another rope-making material, and they are used in weaving carpets as well. All these fibres form part of the bast of the plants from which they are stripped.

Looking at the stem bundles we can recognise the features whose acquaintance we made in the root. Indeed, it is important to remember that the water-pipes of the wood and the sieve-tubes of the bast run continuously through root and stem and out into the leaves, and even into the flowers. The water-pipes, as you will remember, conduct water and dissolved mineral salts (the rising sap) from the root to the leaves, where they are used in manufacturing food, and the food is distributed through the plant largely by means of the sieve-tubes.

When Janet and I were learning these facts from Uncle Fred I often used to think, " It's all very well to be *told* them, and of course I suppose botanists know what they're talking about; but I wish that for one moment I could get some of the reducing stuff in *Alice in Wonderland* and then crawl inside a plant and *see* the works in action." I think I must have expressed something of my feelings to Uncle Fred when we were talking about the flow of sap through the water-pipes, for he told me that, although, not being a magician, he couldn't entirely fulfil my wish, he could go a long way towards it. Then he sent me for a bottle of red ink while he went out and pulled up an assortment of plants—Groundsel, White Campion and Antirrhinums. He watered down the ink a bit to make it go farther, and partly filled some of his empty tobacco tins with it. In some of these he stood entire plants, with half the length of their roots clear of the liquid, and in others he put cut stems—and then, in his calmest and most aggravating manner, he told us to run away and play for half an hour or so.

We were back long before time was up and, although my uncle teased us for a bit and assured us with an air of maddening calm that there was no hurry, we soon persuaded him to tell us what was going to happen. He cut across the stems of some of the Groundsels and Antirrhinums at some distance above the ink, and in each of them you could see plainly a ring of red dots.

" Those are the water-pipes in the wood-bundles," he explained. " I can't let you inside them, but you see for yourselves that the red ink has risen thus far up the stems. And it's risen in the water-pipes and nowhere else. The sap rising from the roots follows the same course. Now let's examine the bundles from another angle."

Then he scraped the epidermis and cortex off a piece of stem, until presently, having come to the wood, he showed us the water-pipes running up the stem in neat, parallel lines of red.

Well, in another hour or less the ink had reached the tops of some of the other plants, which were ten or eleven inches high, and also travelled right out to the ends of the branches and into the veins of the leaves, while, when we chopped a root of Groundsel across, we saw that the centre—where, you will remember, the wood-bundles of a root are placed—was full of it. Later still the highest flower-bud of one of the Antirrhinums began, as Janet put it, to go red in the face and, when we turned to see how the White Campions were faring, we discovered that the petals of the flowers were daintily decorated with delicate red lines which really quite added to their beauty, although I very much doubt if so much red ink was good for them. It wasn't much good to the table-cloth either, for we got into a most awful mess in handling the inky plants, and I suppose we ought to have removed the cloth before we began—but you can't think of everything. Anyhow, it was great fun, and it demonstrated beyond doubt that the water-pipes form a connected conducting system through the root, stem and leaves and even parts of the flowers.

Now would you like to hear Janet's reflections on stems?

It seems to me, from what I'm told,
  That stems are clever and stupid too;
Which is a contradiction bold,
  But justified by what they do.

They're quite content to stand (or sprawl)
  And bear the leaves the live-long day—
Just like the hat-rack in the hall,
  And just as stupid, *I* should say.

Yet, like mechanics, they have knowledge
  Of how to build their structure best;
Which, as they've never been to college,
  Is rather clever, I suggest.

But, when they're young, they keep upright
  (Could any artifice be madder?)
By drinking water day and night
  Till every cell is like a bladder.

I hope the roots know when to stop
  Supplying them, for such a thirst
Might make them drink till, with a pop,
  Their million swollen cells all burst.

Well, then they're water-carriers too;
  They're builders, using cells for bricks;
They're porters, for they carry through
  The foodstuffs for the leaves to mix.
In fact such varied things they do
  They're just a box of conjuring tricks.

At this stage we will break off for some experiments and observations:

In order to study the effect of one-sided light on stems and leaves, you should place some young pot-plants near a window and notice how the stems bend over and the leaves place themselves at right angles to the direction of the light. Turn the pots round and watch the stems and leaves adapt themselves to the new situation. Finally, place the pots out of doors, where they will be evenly illuminated.

Seek out plants growing in shady places, and observe how long and pale and limp are their stems as compared with those of plants growing in an abundance of light.

Open up the buds mentioned on p. 48, and as many others as you can find, giving especial attention to trees. Observe, in each kind of plant, the different descriptions of scales, the presence or absence of varnish, down, etc., the position of the buds on the branches and whether or not they contain flowers as well as leaves. Make drawings of the various buds in the different stages of opening. Identify in winter as many trees as you can by the shape and position of their buds: *e.g.*, those of the Beech are brown, slender and fine-pointed and they grow singly; those of the Common Ash are black and bluntly pointed and they grow in pairs.

CHAPTER VI

MORE ABOUT THE DOINGS OF THE HUMBLE SERVANT

ONE day my uncle suddenly shot out a question to Janet and me: "How fast do you think the sap rises in plants?"

Well, of course, I'd never thought about it before and, when I did so then, I only formed a vague notion of its oozing upwards at such a rate that an aged snail with one horn, so to speak, already in the grave could give it a good start.

Janet, of course, had to be clever, so she yelled out "An inch a day!" and then shut up quickly for fear she'd made a howler.

My uncle smiled. "Well," he said, "I've asked you a question I can't answer very satisfactorily myself. You see, the rate varies tremendously, according to the plant, the season of the year and other conditions. What I really wanted you to know was the astonishing pace it makes in some extreme cases. In trees it may be only a few inches an hour, but sometimes it's as much as six feet an hour."

"Six feet an hour!" I exclaimed. "Why, that's a foot in ten minutes—over an inch a minute."

"Gee!" murmured Janet (enviously, I think). "You're coming on, aren't you?"

"But listen to this, old chap," said Uncle Fred. "Some of the climbing plants can beat that hollow—the Cucumber, for instance. Its stems are long and slender and, of course, it doesn't stand upright. The sap travels along them sometimes at a rate of twenty feet an hour. How much is that a minute?"

We were both too completely flabbergasted to work it out at once, but Janet was first off the mark this time.

"Four inches!" she shouted, and you can figure it out for yourselves to see if she was right.

Let us return to the bundles, for they have not told us all their secrets yet. They form, with the thick-walled cells and additional fibres of the cortex I mentioned in the last chapter, the principal strengthening *material* of the stem; though we must always remember that, in young green stems, it is the swollen condition of the soft, juicy cells that keeps the structure firm and taut, and so helps it to hold itself up and avoid being round-shouldered.

It is by means of the bundles that stems grow in thickness and, if you have ever stopped to wonder how the slender stem of an Oak seedling, for instance, manages to develop into the mighty trunk of the full-grown tree, you will want to know how such a vast change is brought about. Well, the method is very slow and very well planned, and to explain it I shall have to introduce you to a new feature. It is present in roots as well as in stems, but its activities are easier to follow in the latter. Lying between the wood and the bast of each bundle of the young stem, like the meat in a sandwich, is a thin layer of soft cells that possess the same wonderful power as those vital cells we saw in the growing points of the root and stem—the power of creating new cells by dividing, then growing to their original size and dividing again, and repeating the process indefinitely. This layer of cells is called the cambium. The new cells which it forms on its inner side—*i.e.*, next to the wood—become additional wood-cells (water-pipes, etc.). Those formed on its outer side—*i.e.*, next to the bast—become additional bast-cells (sieve-tubes, etc.). But this is not all. Strips of cambium appear in the spaces *between* the bundles and begin to make fresh wood and bast there. In time the strips join up with the cambium of the bundles to form a

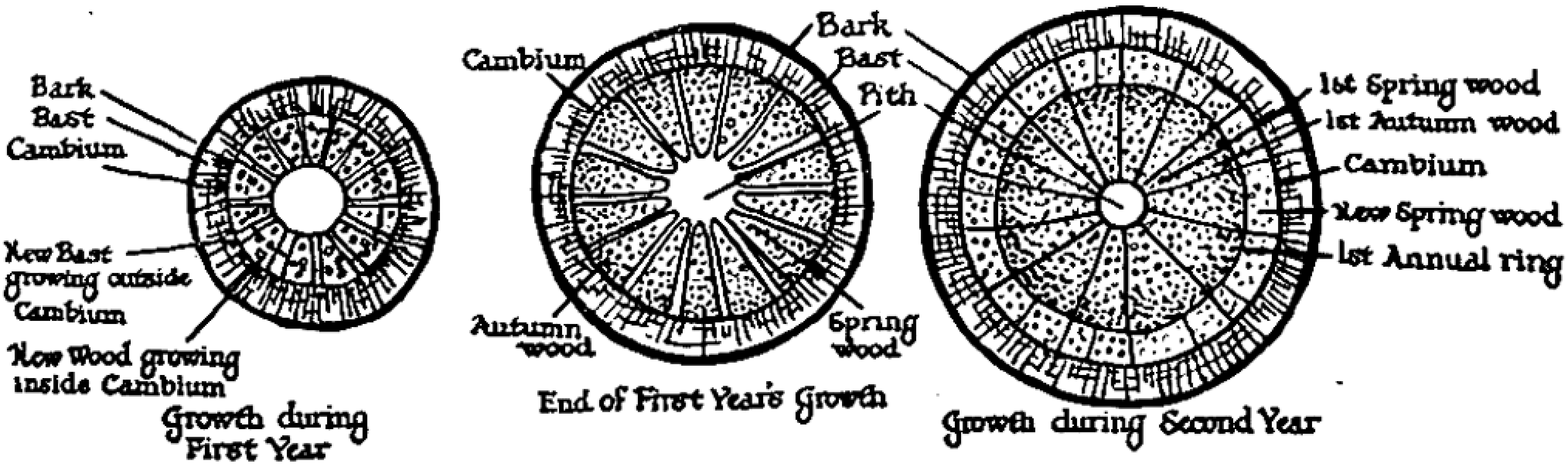


DIAGRAM SHOWING GROWTH OF CAMBIUM

complete ring of cambium, producing wood towards the inside of the stem and bast towards the outside. Every year the cambium makes a fresh ring of wood and bast, and that is how the trunk of a tree, and its branches as well, become thicker and thicker.

You will appreciate the necessity for this increase of growth in the wood and bast of trees (and also of perennial woody shrubs) if you reflect how the other parts of the plant are multiplying. The roots are putting out new side roots and the trunk is developing new branches and leaves. The enlarged root-system is sucking up greater quantities of water and the leaves are making extra food. Hence new water-pipes and sieve-tubes are required to conduct the increasing flow of supplies, and more strengthening materials are needed to support the additional weight of the new growth. It is the busy little cells of the cambium that shoulder this arduous work.

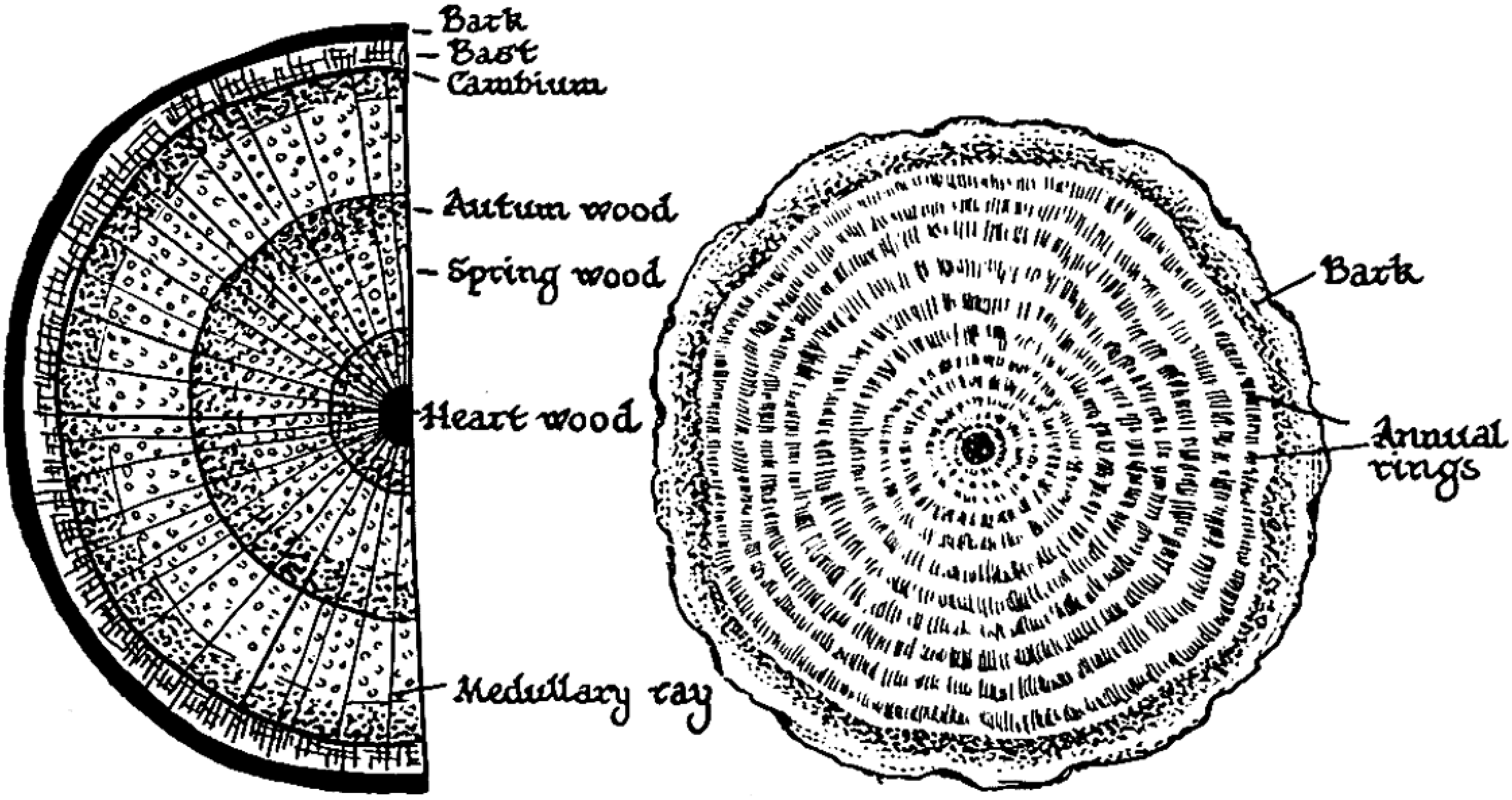
In our common annual herbs there is not the same need of this additional growth, for the plants do not live long enough to develop a heavy system of branches. Accordingly, their stems do not thicken to any great extent. None the less we do find the beginnings of thickening by means of the cambium in many annual stems, though the process does not as a general rule develop very far.

In trees, as time goes on, the cambium forms so much wood that it extends in a solid mass right into the centre of the trunk, the original pith generally disappearing altogether. The cambium always makes vastly more wood on its inside than bast on its outside. In the stump of a felled tree you can see that practically the entire trunk consists of the solid wood. The cambium, which is too inconspicuous for you to distinguish, forms a thin ring outside the wood. The bast forms a thicker ring outside the cambium, while outside that is the bark. I must impress on you that this is how the trunk appears when cut *across*. If it were cut *lengthways* you would see that the wood, cambium, bast and bark really formed a series of upright cylinders or tubes, one inside the other.

Another feature to be noticed is that of the streaks or rays that run, somewhat like the spokes of a wheel, from the outside towards the centre. These rays are to be found in the smaller plants, and in roots as well as in stems, but they are more striking in trees.

They consist of lines of cells that convey water and food *across* the stem to the different tissues, and serve also as one of the storage-places for surplus food.

I expect you know that you can count the annual rings of wood in the trunk of a felled tree and so tell its age. (You cannot count the rings of bast, because they all get crushed together and form only a thin band.) I wonder, though, if you know how the dividing line distinguishing each ring is formed? Every spring the cambium, which has been resting during the winter, commences making the ring of new wood-cells on its inside, and, as the roots are sending up copious supplies of water at that season, the cambium makes the new water-pipes wide and numerous, so as to cope with the flow. The wood, accordingly, acquires a somewhat loose or open texture. Towards the end of summer the roots begin to work less vigorously, so that the water-supply slackens. The water-pipes which the cambium makes at this time are correspondingly narrower and fewer. This, and the formation of an extra large number of woody fibres, gives the later growth a closer or more compact appearance. Then the factory closes down for the winter. Once again spring arrives,

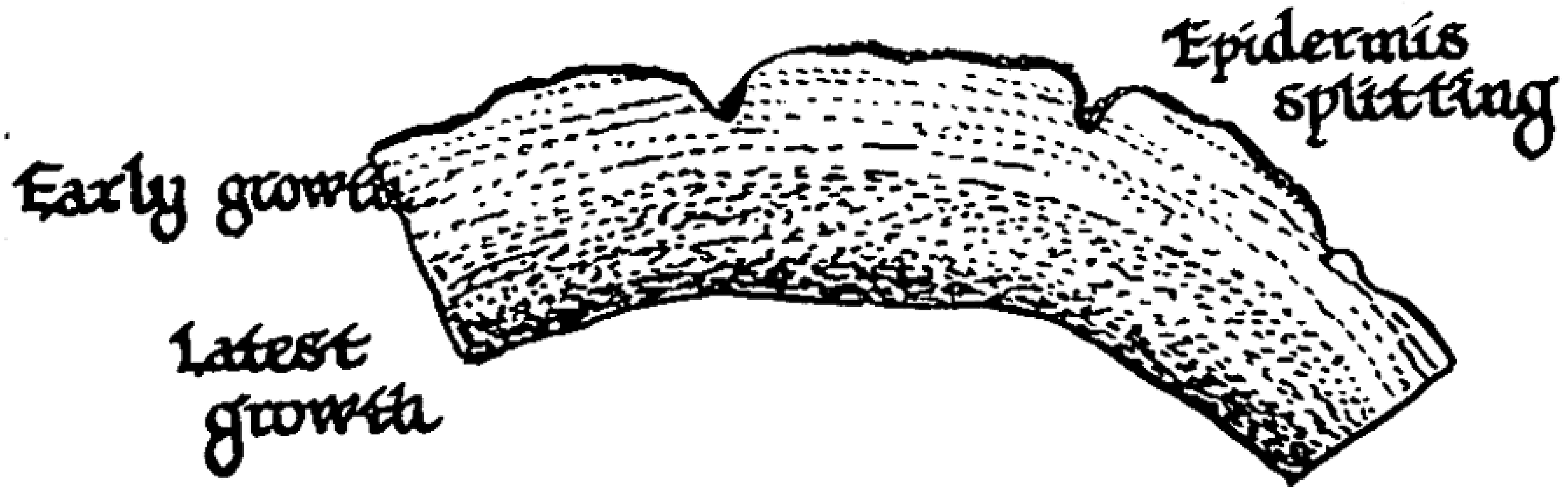


Cross-sections of the Trunks of Trees, showing Annual Rings of Growth and Formation of Autumn and Spring Wood and once again the roots begin working at high pressure. The cambium responds by constructing numbers of wide water-pipes, as it did in the previous spring, and it is the contrast of the " open " wood of this period with the closer growth of last autumn that makes the dividing line showing where last year's growth stopped and this year's began.

In many trees, when they are some years old, the outer or later formed rings of wood are of a lighter colour than the more internal part. In such cases it is mainly through the water-pipes of these outer rings that the sap ascends, for which reason they are called the sapwood. The rest of the trunk is dead wood (which is by no means the same as decayed wood), and it is called the heartwood. It has given up carrying water, and now serves almost entirely for supporting the increasing weight and spread of the branches. Heartwood is far more durable than sapwood and more suitable generally as timber for building and making furniture, because, as there is less water in it, it is less liable to warp or shrink in drying. Moreover, it affords us some of the most highly prized timbers used in choice cabinet-work. Our rich and glossy mahogany furniture and the splendid counters and other fittings which you see in shops are all hewn from the heart of the Mahogany tree. The heartwood of the Walnut tree, too, is of great value. It makes beautiful furniture, and it is also used for gun-stocks and the blades of aeroplane propellers. Satinwood and ebony are other highly prized timbers. The sapwood of the Ebony tree, whose home is in the East Indies, is white, but the heartwood is as black as—well, as black as ebony, and as hard as a stone.

It is because of the dead condition of the heartwood that very ancient trees are often still able to survive though their trunks have become completely hollow. The old wood, in these cases, has actually decayed, but the flow of water up the sapwood and the return flow of the manufactured food down the bast remain unaffected. So long, therefore, as the surviving structure is sufficient to support the branches, the ancient monarch manages to hold up its venerable head in the air. Some of these veteran trees are hundreds, even thousands, of years old, and seem capable of living for centuries yet. I have heard of one old Yew tree whose hollow trunk is roomy enough to admit a man on horse-back and allow him to turn round with ease. No doubt many of you have read of the " Wawona Tunnel Tree ", the great Sequoia of California, which had a twenty-six-foot tunnel cut clean through its base in 1881 to make a roadway for vehicles. There is a splendid photograph of the tree in the Natural History Museum, South Kensington, showing a body of horsemen riding through. There was once, too, an old backwoodsman who, finding a hollow low down in the trunk of one of these giants, enlarged it with his axe till he had hewn out a room within, and there he lived quite snugly, rent free, for many years.

What happens to the original epidermis of a stem that grows in thickness as the result of the activity of the cambium? Obviously it must often be subjected to a very great strain. Well, in the majority of annual stems nothing very striking occurs. The stems thicken comparatively little, and the epidermis usually manages to carry on without splitting until the stem dies down after its one season of growth. With trees and shrubs, however, it is different. Inevitably the epidermis is ruptured; but a new covering of cork is formed beneath it, and all is well again. The cork, in fact, affords much better protection from excessive heat and cold and evaporation of sap than the original covering could have done. As the stem or trunk ages and continues to thicken, fresh layers of cork are formed from time to time somewhere within the previous layer, the outer tissues split and so the bark is formed. In some trees the split tissues fall off every year, but often they remain on the trunk and branches and the fissures become deeper and wider until they form the rugged bark you see on such trees as Oaks and Elms. The corks we use to stopper



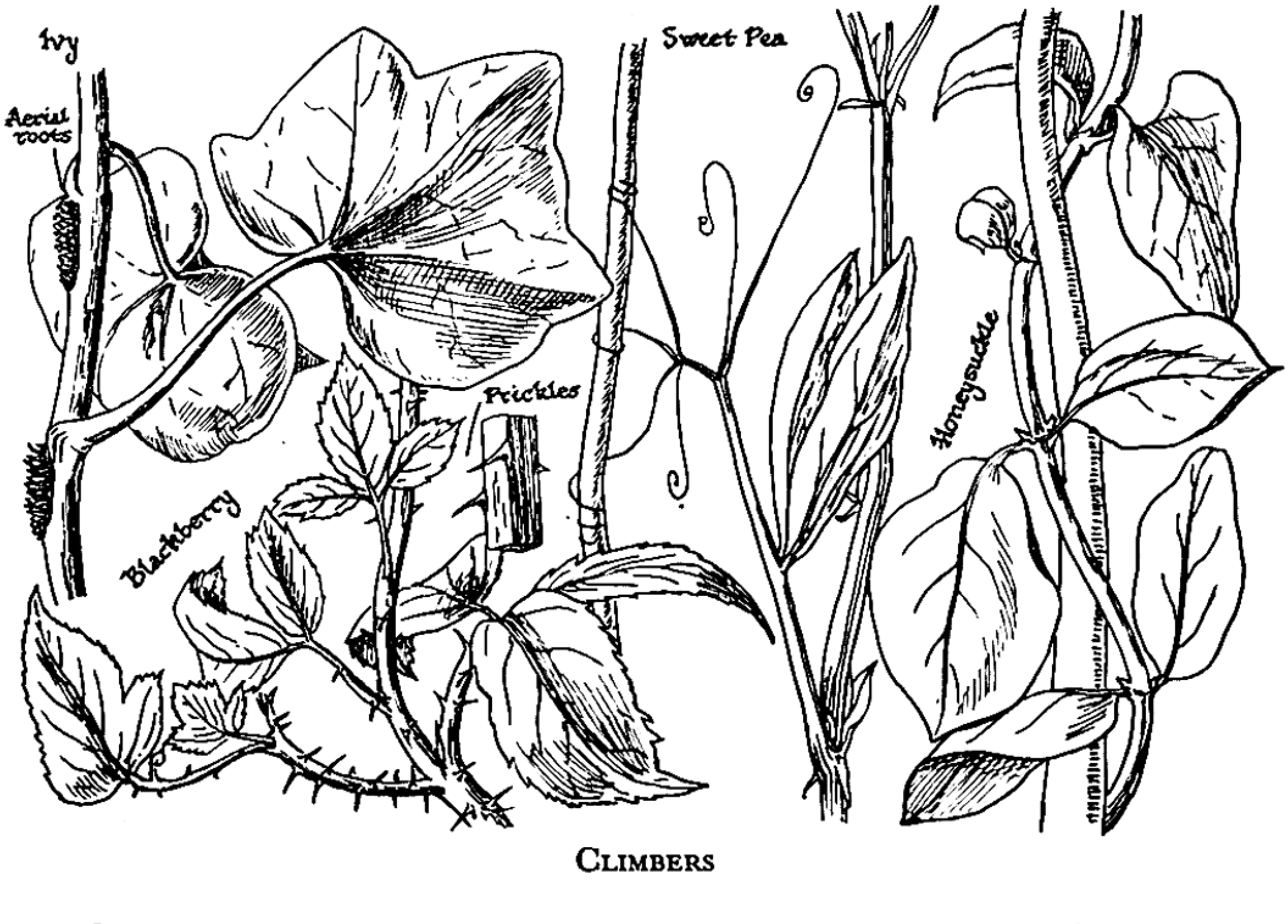
THE GROWTH OF BARK

bottles are made mainly from the cork-layers of the Cork Oak, which are stripped off in big slabs every ten or twelve years.

The tree's overcoat of bark is made of such durable material that it often outlasts the trunk it clothes, as a suit of armour might outlast the knight of old who did battle in it. Birch-bark is particularly durable, and various kinds of it are used abroad for making canoes and shoes and for roofing houses. Some of the primitive Australian tribes made their war-shields from the bark of native trees. It is curious to reflect that there may still be lying under the streets of London a number of ancient water-pipes formed out of the hollowed trunks of Elm trees. Some years ago I saw some of these primitive vessels dug up, and I have read of others in which the mud-encrusted bark was still intact, though the pipes had been in the ground for nearly three hundred years.

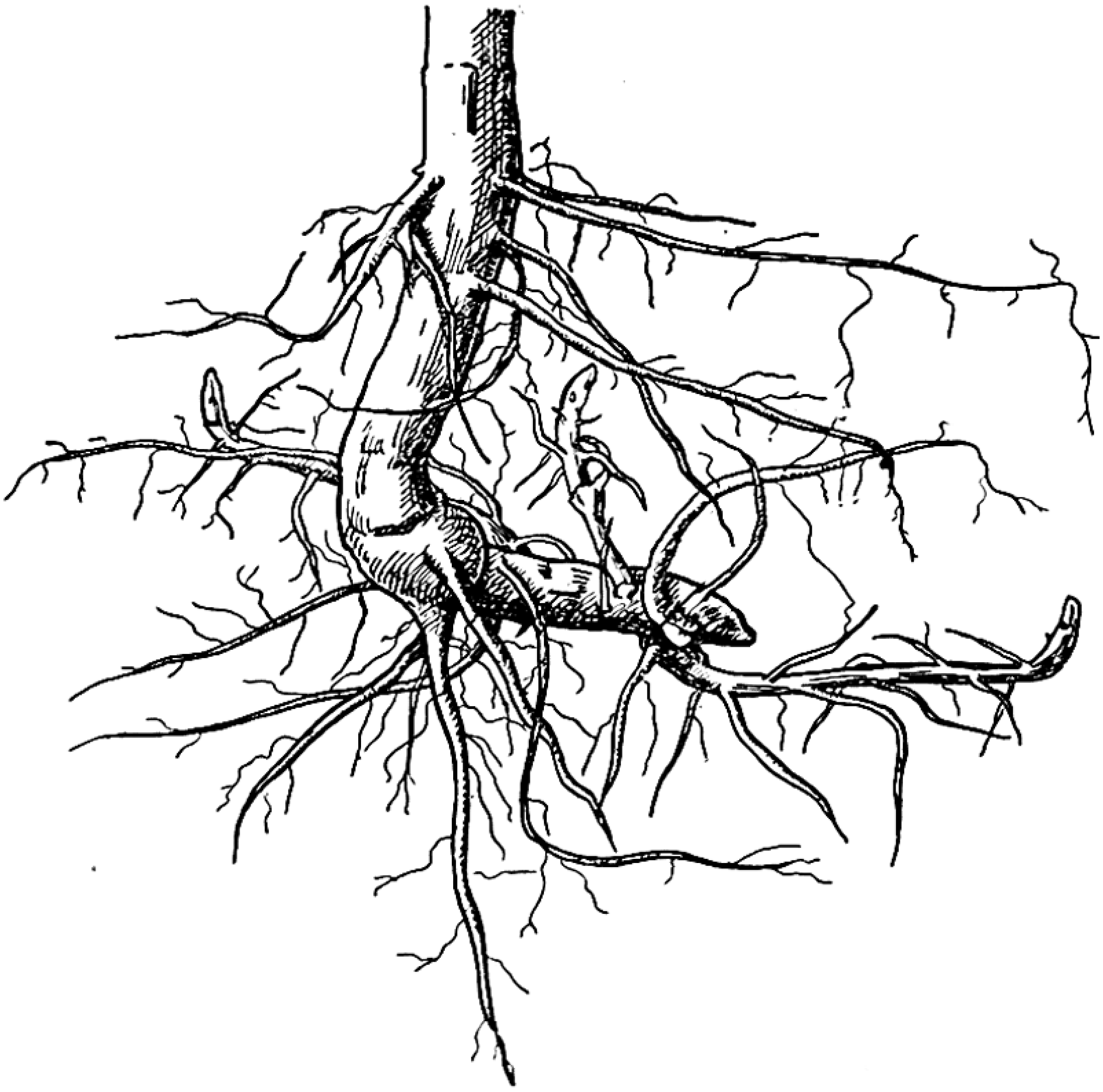
The bark of Oaks, Birches and many other trees contains large quantities of " tannin ", an acid used for tanning hides—that is, converting the skins of cows and other animals into finished leather. Without some such substance as this you would have to wear shoes of raw hide, like some of the moccasins of the Red Indians. The horrid medicine quinine, which we take for curing a cold, is an extract from the bark of the Cinchona tree, a native of Peru. There is a curious tale told of how the value of cinchona was first discovered. Some Cinchona trees growing in Peru were one day blown down in a gale and fell into a pool from which the residents were in the habit of drawing their water. After a time the water became so bitter that no one would drink it. Then one day a man staggered down to the pool delirious with fever. In his suffering he drank deeply of the bitter water to quench his raging thirst. From that moment his fever began to abate, and soon he was quite recovered. In this way attention was drawn to the trees lying in the pool, and very soon the healing powers were located in the bark.

Stems are variable creatures. Their normal habit is to stand erect, but often they are too feeble to do this and, instead, they either sprawl more or less along the ground or climb upwards by means of such supports as they can find in their way. These climbers have various ways of helping themselves along. In the Honeysuckle, for instance, the stem itself twines round and round its support. In Sweet Peas and other plants delicate tendrils are produced to do the twining. Other plants, such as the Blackberry, the Dog Rose and the Goosegrass, scramble up out of the crowded growth of the hedge-banks and gain the light and air by means of business-like hooked prickles set on their stems, and sometimes (where we least expect them) on their leaves as well. Like so many ruthless pirates boarding a helpless ship, they use their hooks in the manner of grappling-irons, fixing them on the neighbouring plants, and so hoisting themselves vigorously upwards. These organs, like the thorns of the Blackthorn, serve also to protect the plants from browsing animals, as well as from the two-legged creatures who come greedily seeking their fruits. The Ivy has a method of its own. It produces, all along the shady side of its stem, a number of roots, which it drives into the tree or wall serving as its support. These aerial roots, as they are called, do not feed on the tree, but merely serve as holdfasts, though, when the Ivy stems become thick and leafy, they injure the tree, often fatally, by choking its growth.

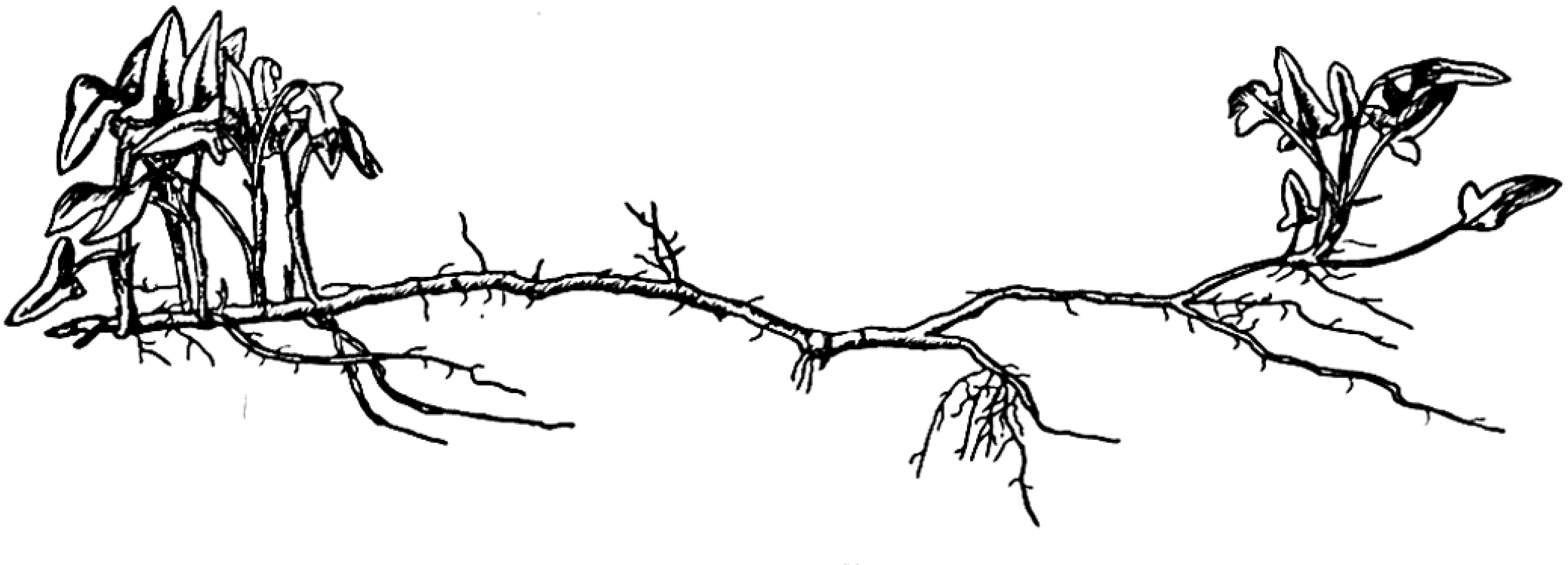


CLIMBERS

Some plants, in defiance of all natural laws, send out stems or

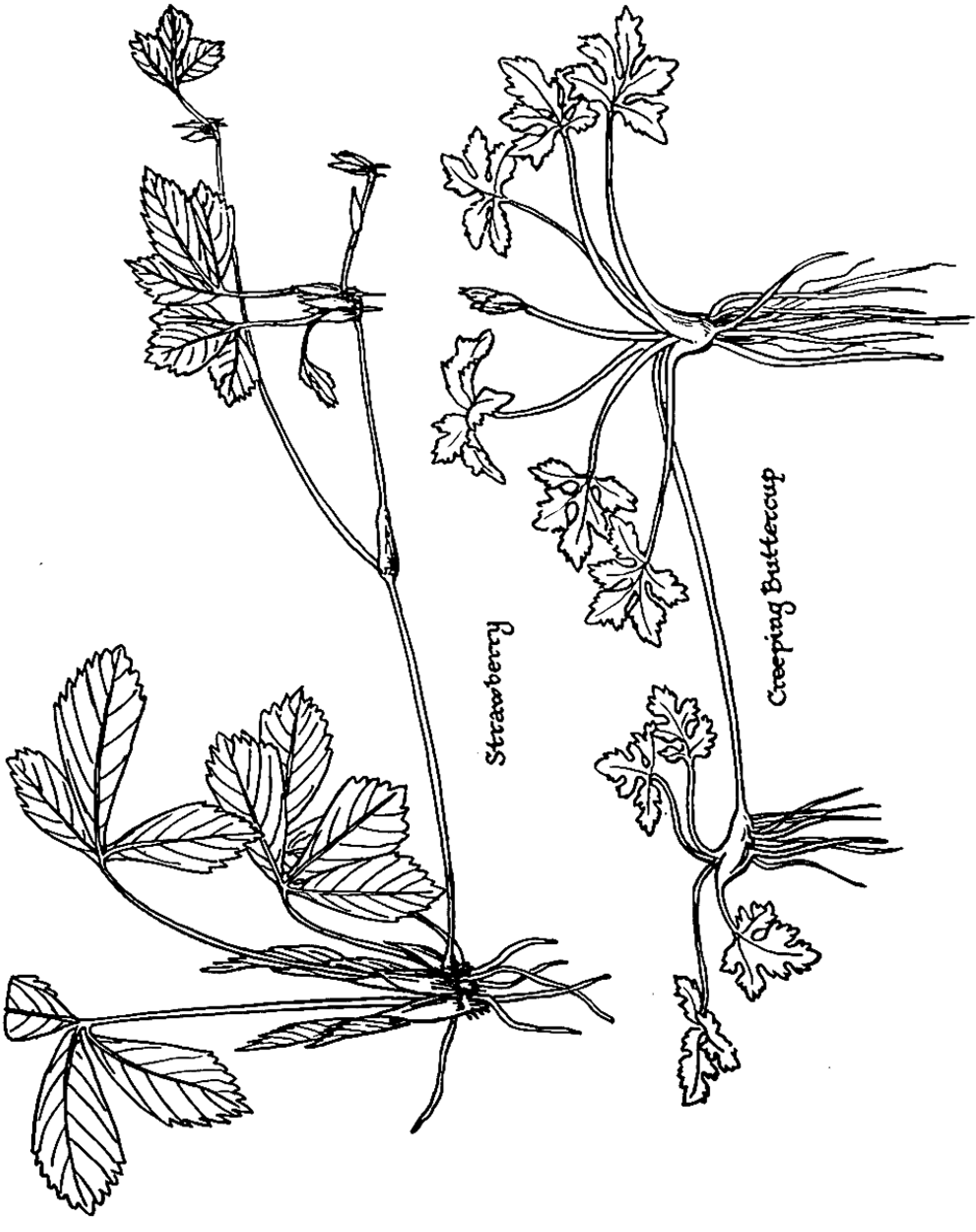


Dwarf Sunflower Rhizome



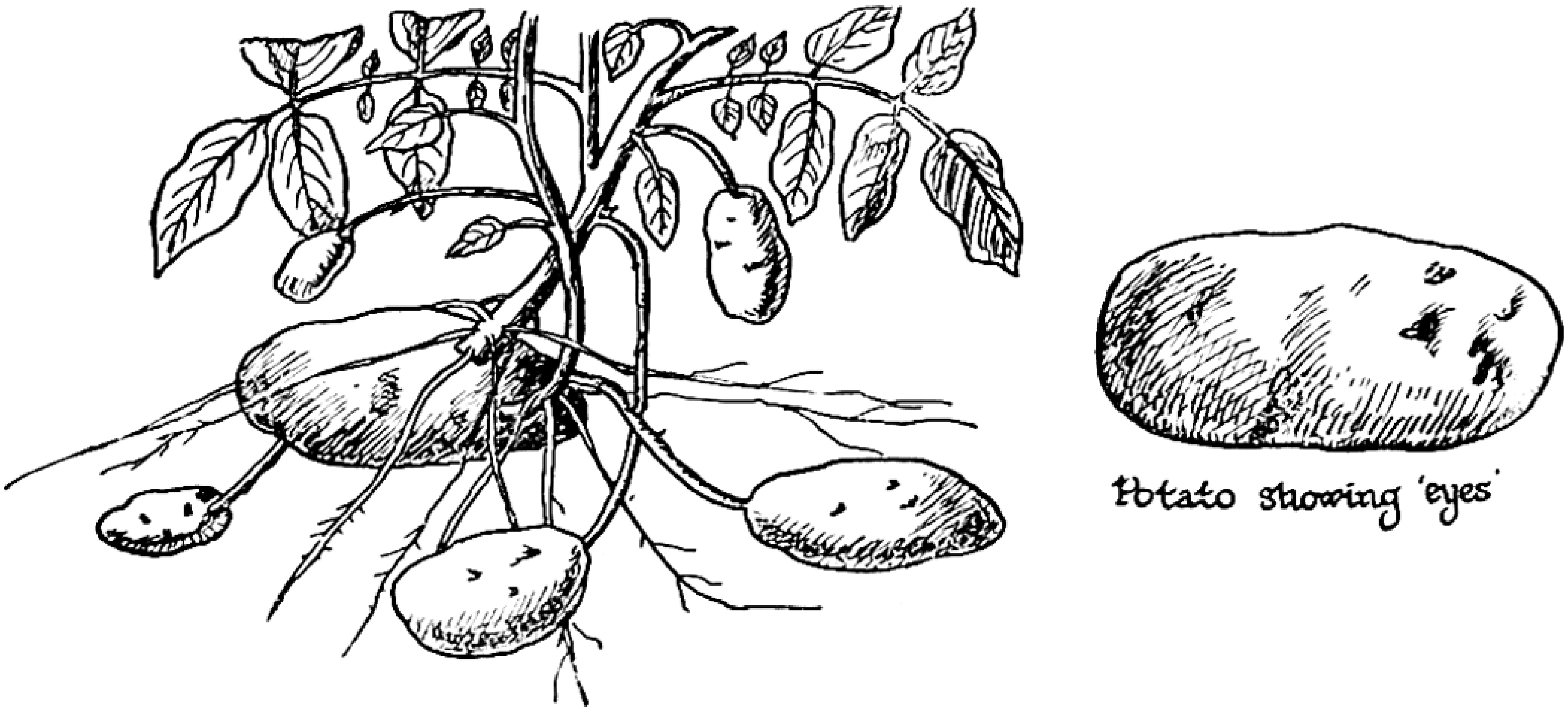
Wood Sorrel Rhizome

branches that actually invade the province of the root and grow underground. You might take many of these underground stems for roots, and with good reason, for they look like roots. They



STRAWBERRY AND BUTTERCUP, SHOWING RUNNERS AND NEW PLANTS have, however, certain incurable habits that strip them of their disguise. One such habit is the production of leaves and buds, and it usually exposes their true character, for roots do not normally produce buds, and they never bear leaves.

Many of these underground stems run along just under the surface of the soil, throwing out roots and buds that develop into new shoots or new plants. Examples are the underground stems, or rhizomes as they are called, of various grasses and those of the Wood Sorrel and the small Sunflower. In the Strawberry and the Cinquefoil the runners creep along *above* the ground, but they produce new plants in the same way, and these presently become separated from the parent plant by the decay of the runner. The underground parts of Potatoes which bear the tubers we boil are stems, though you would hardly think so. The tuber itself is the end of a branch enormously swollen with reserve food. The " eyes " are really buds and, if you plant the tuber in soil, the bud will grow into a stem, and thus establish a new plant that will nourish itself on the food stored up for that purpose in the tuber.

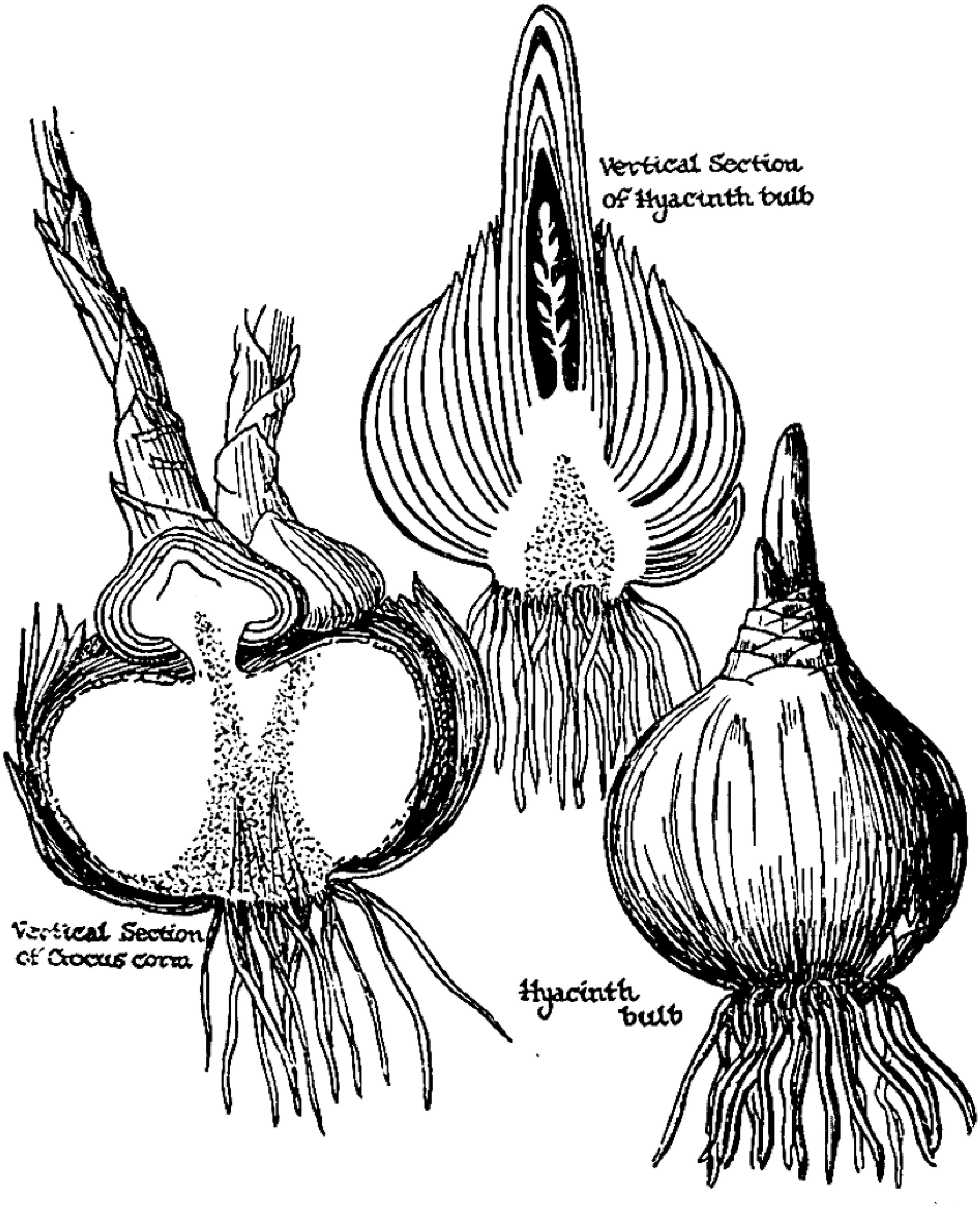


Potato showing 'eyes'

POTATO PLANT, SHOWING TUBERS AND " EYES " (BUDS)

Do you know how potatoes first came to be eaten? I don't suppose you do, and I don't myself really, but I can tell you a story about it. The first people who were presented with the strange new tubers sat down and began to eat them raw—knowing no better, of course. Then they exchanged glances and grimaced expressively.

"Nasty horrid taste!" said one.


Vertical Section of Hyacinth bulb
Vertical Section of Crocus corm
Hyacinth bulb

Bulbs and Corms packed with Reserve Food

"Disgusting!" said another. "And so hard. The fire's the place for them."

So they threw them on the fire.

Presently one of the potatoes, now nicely roasted, fell out through a gap in the bars, and one of the folks ran to pick it up. He sniffed it—and it smelt good. He felt it—and it was no longer hard. He sank his teeth into it, and it tasted delicious. And that, so they say, is how we learned to cook potatoes.

The bulbs and corms produced by such plants as Lilies and Onions and Crocuses are likewise underground stems packed with food. These details, however, are not frightfully interesting, and, if I give you any more, I am sure you won't remember them. The point you should mark, however, is that these special forms of stem are devices for producing new plants and storing up reserves of food for them or for the parent plant itself next year.

And now Janet says it's fully time that we had some more verses for a change, so I will give you what she calls her

Full and Complete Guide to the Annoying Variations
of
THE STEM.

The stem grows upwards from the soil,
  Or dives below for sport.
It always stands erect unless
It climbs or clambers more or less,
Or twines itself in fond caress
  Around a strong support,
Or crawls, or creeps, or, I confess,
  Does nothing that it ought.

It's often tricky in its ways
  And fond of strange disguises.
It tries to cheat us in the forms
Of bulbs and tubers and of corms
That hide themselves among the worms,
  With other low devices
No self-respecting stem performs,
  But heartily despises.

The honest stem hangs out the leaves,
  Like washing on a line.
It fetches water from the roots
And carries it to leaves and shoots,
And slaves for flowers and buds and fruits
  Without a single whine.
I daresay it would clean the boots
  If there were boots to shine.

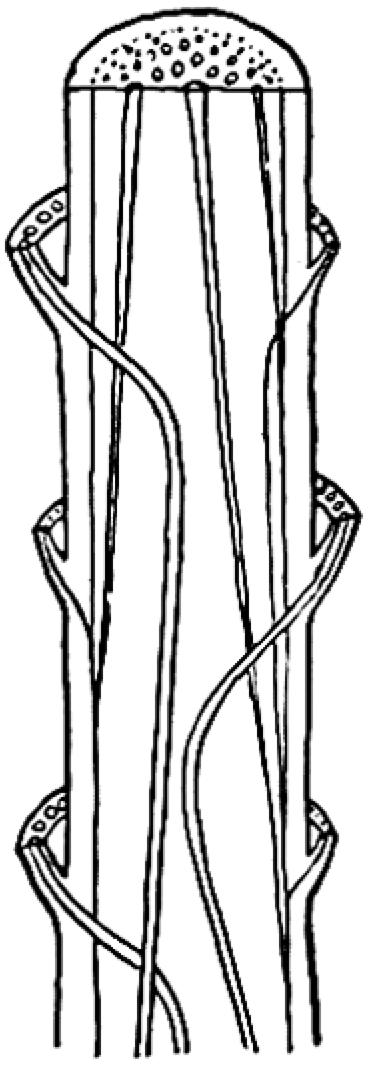
After descending to such frivolity as this, I think I may as well continue in the same vein for a while and tell you something entertaining about this deceptive organ. I have already described a queer old superstition about a root, and you may be amused to hear some tales about the underground stems, though I daresay the actual roots were often confused with them. The White Bryony was believed to be an excellent remedy for a black eye—far better, indeed, than the lump of raw meat favoured as a rough-and-ready cure. The Black Bryony was considered equally effective for chilblains. There was nothing like Comfrey for mending broken bones, and Solomon's Seal was highly esteemed for removing pimples and freckles and generally improving one's complexion. From what an old writer says about the latter plant, it would seem that husbands and wives were sadly quarrelsome in his time, for he specially recommends the rhizomes for removing " any bruise, black or blue spots gotten by falls or woman's wilfulness in stumbling upon their hasty husband's fists ".

When people found themselves getting too stout, they drank broth containing Fennel, and fondly hoped it would make their figures sylph-like. Daisy " roots " restricted growth in a more surprising manner. They too were boiled in a broth and then given to puppies to keep them small. I hope the puppies relished it. There is an old tale, too, of a fairy named Milkah who, having adopted (kidnapped, I expect) a human child, fed it on a similar concoction to prevent it from growing beyond the proper size of a fairy.

One of the strangest of the old stories was that, if you were running a race and chewed a piece of a Garlic bulb, none of your competitors could overtake you. Perhaps this ridiculous fancy arose from the strong smell of the plant, for there was another story which said that jockeys in a race used to fasten a Garlic bulb to the bits of their horses, because, if any of the competing mounts drew up with them, the beasts would scent the bulb and promptly fall behind again in disgust!

To turn to a more practical side of the subject, the Ginger plant gives us a delicious sweetmeat. The plant grows in the East and West Indies and other parts of the world. The underground stems, and the young shoots as well, are scalded and dried, and then they may be either powdered, or candied, or preserved in syrup. I need do no more than mention ginger-beer and the real old-fashioned ginger-bread to complete your appreciation of the plant's services.

Another practical use made of certain plants having a strong system of underground stems is that of binding together sandy shores, newly-made railway embankments and similar loose or unstable ground. In many places along our coasts there are huge tracts where the sand accumulates in great mounds and hills and continually shifts under the action of the wind and tide. You would not expect that any plant could maintain itself in such loose and arid wastes, yet it has been observed that certain Sea-grasses and other herbs are able to establish themselves there by means of a widespread system of rhizomes and roots. The rhizomes of the Marram-grass, for instance, run along under the sand and send out long roots that burrow feet deep after water. Soon a tangled mass of growth is formed that binds the sand together. Above ground the shoots lengthen as fast as the sand accumulates, continually defeating its efforts to bury them alive. Thus the plant establishes itself firmly. Great tracts of land have been won back for use by the planting of such grasses.



SECTION OF A MONOCOTYLEDONOUS STEM, SHOWING THE ARRANGEMENT OF THE BUNDLES

Seeing that I described the stem as a comparatively unimportant member of the plant, I seem to have said rather a lot about it. I could, in fact, write another hundred pages or so describing its many variations, but I think I have told you enough to begin with and, besides, I want to start on a new branch of our studies that is less crowded with dry details. I must, none the less, say a final word about the stems of monocotyledons. As I indicated before, I am giving only a passing notice to the plants of that group; but I want you to bear in mind that their manner of growth is often quite different from that of the dicotyledons. Here are some of the more important differences in the stem: The bundles have no cambium, so the stems cannot go on getting thicker and thicker in the way that dicotyledons do. In this country there are no large native monocotyledonous trees or shrubs, but only the smaller plants that I referred to generally in Chapter II. The bundles are not, as a rule, arranged in a regular ring, but are scattered irregularly through the stem. Rhizomes and bulbs and corms are found very frequently in this group.

Suppose we go out of doors for a while and amuse ourselves by making some first-hand observations.

It is always interesting to study the stumps of felled trees. You can try to count the annual rings and detect the rays I mentioned on pp. 58 and 59, the different colours of the heart-wood and sap-wood and the character of the bark—whether it is smooth, rough, deeply split, etc. Look out, too, for fallen Birch trees, and observe how often the bark endures as an empty shell long after the trunk has decayed.

Twining plants have some surprises awaiting us. Did you know that the Hop and the Honeysuckle twine from left to right—*i.e.*, clockwise—while the Convolvulus and the Runner Bean twine from right to left? Study all the twining plants you can find, paying particular attention to whether the stems themselves twine or whether tendrils are produced for the purpose. If you mark the position of a twining stem on its support and examine it from time to time later, you can tell how long the stem takes to complete one " circle ".

Look closely into the jungles of growth on the hedge-banks, and make notes and sketches of the various kinds of hooks and prickles which help the crowded plants to climb up to the light.

Drop some weak iodine solution on a cut piece of potato and observe that it turns dark blue. Recalling the experiment on the Maize grain mentioned on p. 15, what do you infer from this? Repeat the treatment on a piece of Crocus corm.

Here is a competition for you: Examine old Strawberry plants, follow up the runners all around, and see who can find the parent plant that has produced the most new plants.

CHAPTER VII

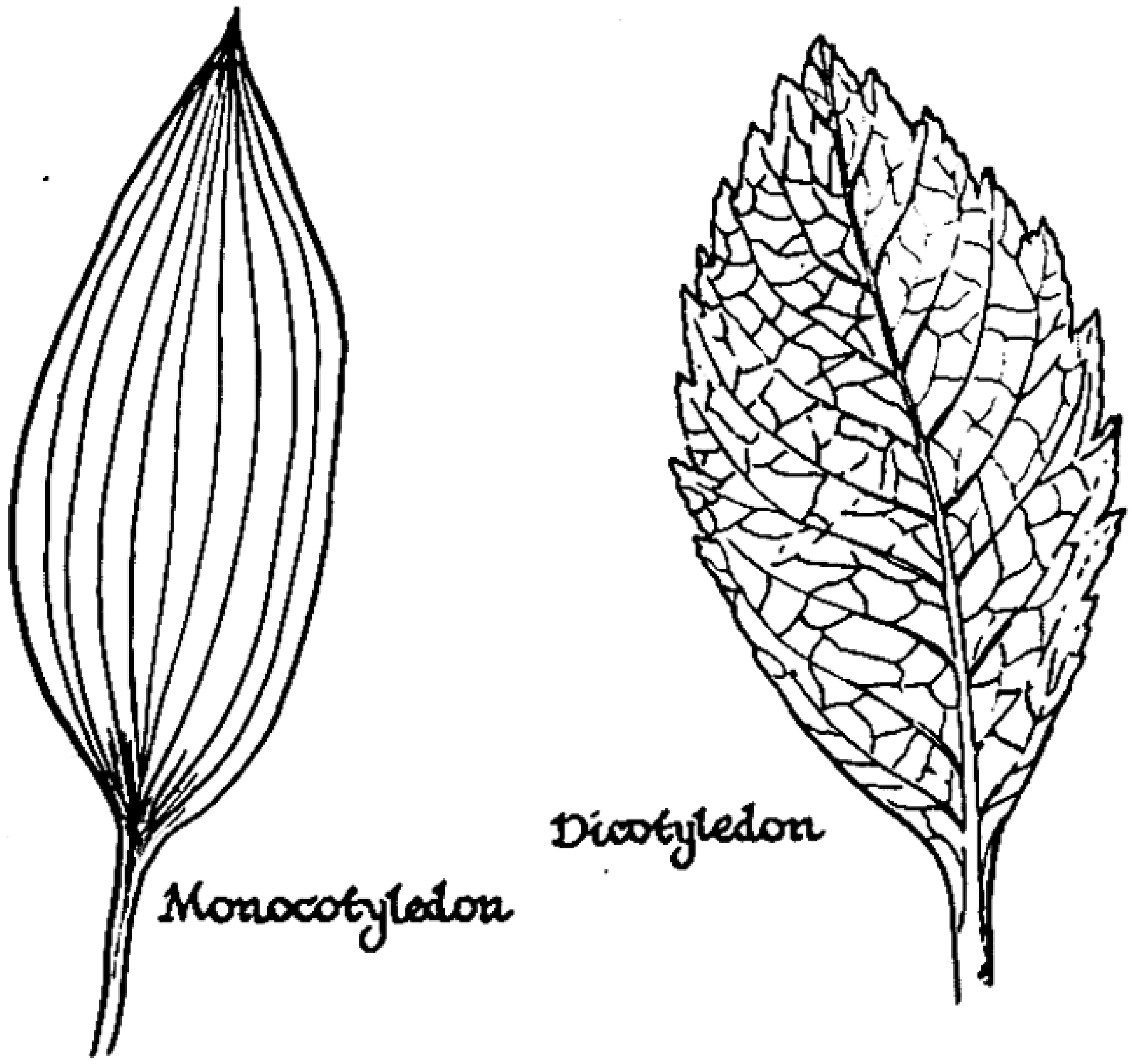
MAGIC IN A FACTORY

WE have spent such a long time talking about stems that I feel as if I had been laboriously climbing up one (like Jack on his Beanstalk) with you struggling after. Our climbing, however, has at last brought us to the leaves, and I rather think they have some surprises to offer. Leaves are some of the loveliest things in the world, and their graceful outlines have been copied for decorative purposes by artists and sculptors in every age and country. But to us, as enquiring botanists, they give not the slightest indication of any activity going on within their cells and, indeed, it is difficult to tell what purpose they serve the plant.

Yet the green leaves are, in one sense, the plant's most important organs, and the work they do holds something of the mystery of magic. It is as if a wizard dwelt unseen in the heart of the quiet blades and, by the mere waving of his wand, performed a series of changes that leave us astonished and bewildered. There is an old fairy tale, told about a Birch tree, in which a queer little Wild Woman of the Forest changed all the dancing leaves to shining gold. I am not going to assert that anything quite so magical actually takes place in the leaves of plants, and yet those leaves themselves do perform such marvels that you might fancy the fairy story was suggested by the transformations that take place in them.

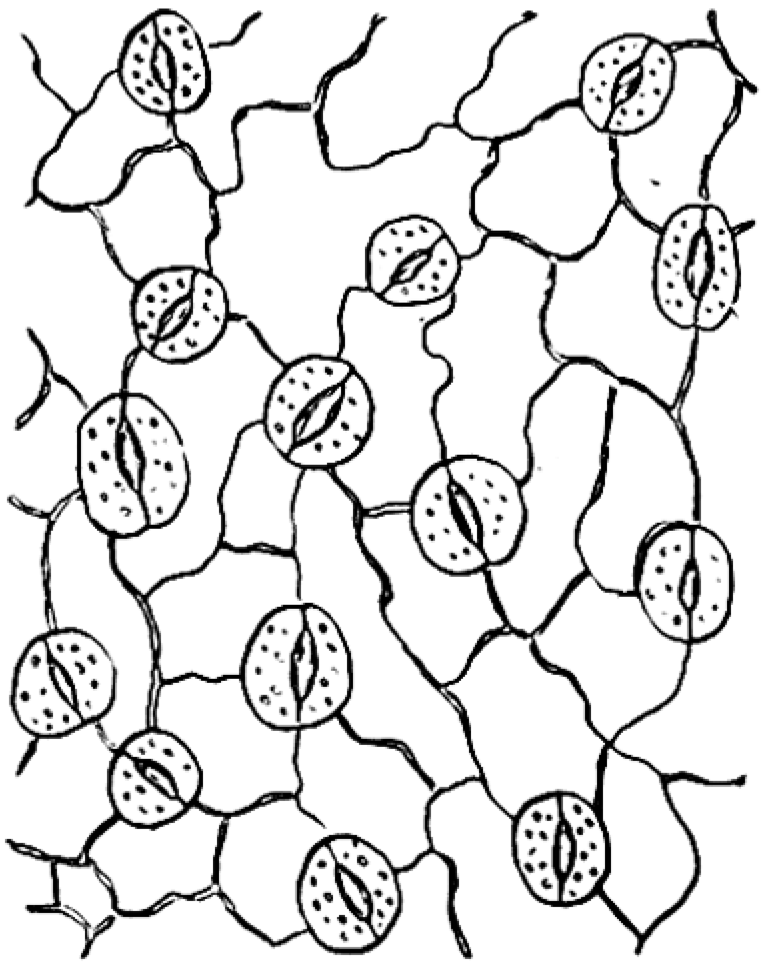
Suppose we take a number of leaves from plants growing around us. We see that they consist mainly of a thin green blade, variously shaped, with, usually, a stalk that attaches them to the stem or branch. The stalk serves to hold the blade out to the sunlight that is so vital to the welfare of the plant, and, being usually sensitive to light, at any rate whilst it is still in the growing stage, may bend and twist so as to place the blade in the most favourable position for illumination. Even when a leaf has no stalk this same movement may be made, for the blade itself is affected by the direction from which the light comes.

The blade is supported and strengthened by a skeleton of veins. These veins contain the wood- and bast-bundles that run from the stem, through the leaf-stalk and into the blade. Thus they not only support the leaf, but they complete the system of food- and water-conducting channels which I have described as running continuously throughout the plant. And here is a feature about the veins that will help you towards distinguishing a dicotyledonous plant from a monocotyledon. In the dicotyledons there is usually a strong central vein acting as the mid-rib of the leaf, or perhaps a number of such veins spreading out in a palmate fashion—*i.e.*, like the outspread fingers of your hand. From these a whole series of smaller veins branches out, with still smaller ones arising from them, to form a fine network throughout the body of the leaf. In the monocotyledons the principal veins lie almost parallel to one another, with finer veins connecting them. If you hold up a leaf to the light you will be entranced by the beautiful tracery that the veins weave.

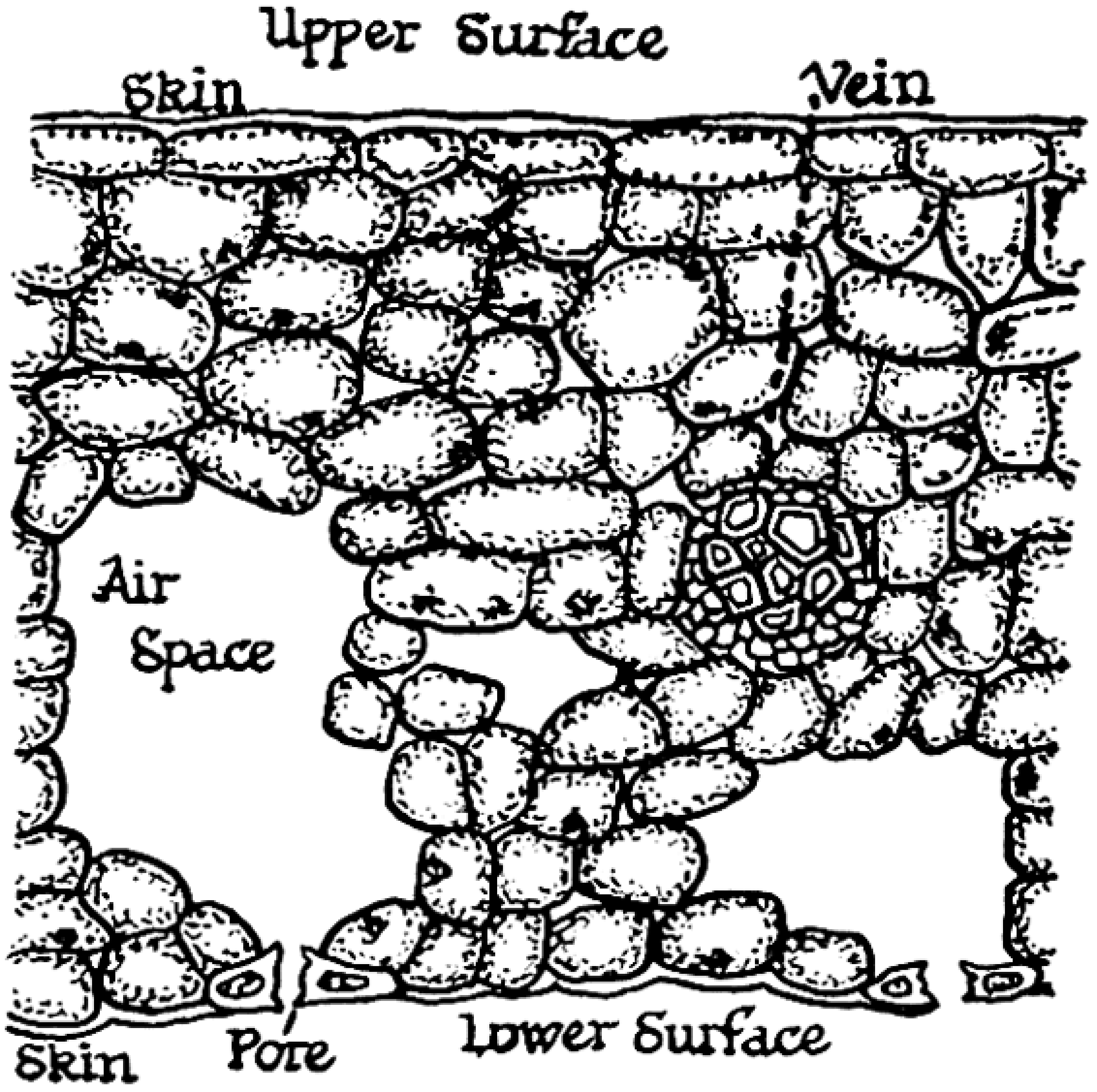


Types of Leaf-veins

The outer covering of the leaf, like that of the stem, consists of a thin skin or epidermis, made up of a single layer of cells. You can see this skin clearly in some leaves—those of the Broad Bean and the Ivy-leaved Toadflax, for instance—by tearing the leaf across, when some of the colourless coat can be stripped off. A leaf-blade is so thin that you do not at first think of it as having any substance or body; yet, if you cut one across and examine the cut edges under a microscope, a whole mass of vividly green cells becomes visible between the skin of the upper and lower surfaces. In a single Maple leaf there are some fifty million cells.



Part of the Surface of a Leaf (greatly enlarged) showing Pores



Longitudinal Section of Leaf

Direct the microscope on to the surface of a leaf, and its all-revealing eye shows something which was invisible to our feebler sight. The skin, and more especially that of the under-surface of the leaf, is pierced by tiny holes or pores. They are so small that a hundred or two of them placed in line (if you can place mere holes in line) would go into a pin's head. And they are so numerous that you might as well try to count the grains of sand on the seashore as to reckon them. A Broad Bean leaflet may contain nearly a quarter of a million of these invisible openings, while a big Sunflower leaf has something like twelve millions.

What is the purpose of these millions of tiny pores? Well, one purpose is to help the plant in making its food. I have several times referred to the food-making activities of the leaves, and now at last I am going to describe them. Stated quite simply and briefly this is what happens. Air is constantly diffusing into the leaves through the pores, and water is reaching them from the roots. With these simple ingredients the leaves, after performing a long and complicated series of chemical operations, evolve a kind of sugar. It sounds quite easy, doesn't it? And it *is* easy—for, as they hang quietly on the stem, bathed by the sunlight and washed by the rain, they are doing it all day long. Yet the cleverest chemists have not yet learned how the plants achieve such a feat. We do, however, know something of the process; but, to explain it to you, I shall have to give you a short lesson in simple chemistry; for the food-making of plants amounts really to a series of chemical operations, such as those you carry out at school, only far more delicate and complicated.

When sugar is analysed by chemists they find that it is compounded of three elements—carbon, hydrogen and oxygen—combined in certain fixed proportions. The leaf of a plant makes its sugar of the same materials, and it obtains them in this way. The air we breathe contains the oxygen that is essential to our life and also a small amount of a gas called carbon dioxide. That gas is a combination of carbon and oxygen. It is the source of the plant's supply of *carbon*—one of the three elements which, as we have seen, go to the making of sugar. The leaves receive the carbon dioxide through the pores (which are like an unthinkable number of greedy mouths kept open to take it in), and thence it passes, through some air spaces, into the green cells. The cells, as we know, are constantly receiving supplies of water drawn up from the soil by the roots. Water, like sugar and other compounds, can be analysed. It is then found to consist of the elements *hydrogen* and *oxygen*—the two other ingredients required to make sugar. You will see, then, that the leaf is now in happy possession of all the materials it needs—carbon, which is obtained from the air, and hydrogen and oxygen, which are obtained from the water in the soil.

But something more than mere materials is necessary. You see, the leaf is really a sort of factory in which the green cells are equipped with engines designed to manufacture chemical food. You know, of course, that an engine cannot run unless it is supplied with fuel—petrol in motor-car engines, coal in locomotives. The fuel used in the leaf-cells is nothing more or less than the sunlight around them. How it is brought into use by the plant we cannot say, but it is quite possible that, when it falls on the leaf, it behaves like a discharge of electricity. This would mean that the engines of the leaf-cells were driven by electricity. At any rate the sunlight is trapped by the green cells, and you will realise from this the importance of what I have told you about the habit of stems and leaves, when unequally illuminated, of turning towards the brightest light.

I have said that the light is trapped by the green cells; but, actually, the capture is effected by some unimaginably tiny specks of a green substance called chlorophyll, which are to be found in the cells and which, in fact, give the leaf its green colour. Without these specks of chlorophyll and the sunlight they absorb the engines could not run, but, with their help, the leaves extract the carbon from the carbon dioxide taken from the atmosphere and, working with this and the water (or hydrogen and oxygen) received from the roots, they ultimately produce a supply of sugar.

Sugar, of course, is very delicious to eat in the form of sweets and jam, but I don't suppose you have so far thought of it as one of the important foods that our bodies need—though not necessarily in the form of sweets and jam. To the plant, sugar is even more essential, for it forms a very large part of its food. Some of it, moreover, is used as the basis of a richer kind of food that plants need, and this is where we begin to understand the part played by the mineral salts taken up by the roots. The salts are dissolved in the water travelling up the stem and, when this " rising sap " reaches the leaves, those same active cells that busied themselves in making sugar now combine some of the sugar with some mineral salts to produce a richer compound.

The sugar and the richer compound are both dissolved in water. In this liquid form they are circulated through the plant, largely by means of the sieve-tubes, till every living cell receives its share. *All* these cells (including those of the leaves) then work up their supplies and build up a second kind of food. This kind is called by chemists a *protein* food. " Protein " comes from a Greek word meaning *first*, and it is given to this kind of food because it is of the first importance in building up the protoplasm in the bodies of living creatures, both plants and animals. It is far richer and more elaborate than the first kind of food—the sugar. In fact it is such a complicated mixture of ingredients, and involves such delicate and mysterious chemical processes, that it simply makes our chemists tear their hair when they try to discover how it is put together. They know what the chemical ingredients are—carbon, hydrogen, mineral salts, etc.; but the puzzle is to discover how the plant succeeds (where the human chemist fails) in making them combine in just the right way to produce the nourishing protein food.

I have previously told you that what we commonly speak of as the " rising sap " of a plant is the stream of water and dissolved mineral salts (food *materials*) passing up from the roots to the leaves. The stream of *manufactured* food that I have just described as travelling from the leaves to the different organs of the plant is another kind of sap; while the liquid that swells out the general body of cells is a third kind with a great variety of contents. In ordinary language, however, we include all these three kinds without distinction in the general term " sap ". You may liken the sap of a plant to the blood of animals and human beings, for it serves much the same vital purposes.

So far I have spoken only of the leaves as the primary food-factories. Actually the stem, or any other part of a plant that contains chlorophyll and is therefore coloured green, can help. The leaves, however, are far better adapted for the work, and they are the principal organs employed. So, too, the little openings or pores which we discovered in such countless numbers on the leaves are scattered more sparingly over the other organs above ground. Furthermore, there are some later formed pores of a special kind in the young bark of trees and shrubs which you can distinguish easily as lighter coloured spots or streaks.

Another thing I must tell you is this: As the green leaves depend on the sunlight to drive their engines, the latter must come to a standstill when the sun disappears. Every night, therefore, the factories close down and the work of food-manufacture stops until the next morning.

When the leaves are making more food than the plant needs for immediate use, they store up the surplus, first in their own cells, and later in the cells of the stem and other parts. In so doing they effect some more clever chemical changes. Sugar, for instance, is converted into starch. This is easily done, as starch is made up of the same elements as sugar—carbon, hydrogen and oxygen—though in different proportions. The plant makes the change because starch is more convenient to store than sugar. When it needs to draw on its reserves, it can change the starch back into sugar just as easily as it made the first transformation.

Some leaves never make starch at all, but in the majority of cases starch appears at a very early stage of the food-making process. This is exceedingly helpful to us when we seek to discover the conditions which are necessary to enable a plant to make food. By subjecting leaves to the iodine test we made on the Maize grain (see p. 15) we can tell whether they are making starch or not and, if not, why not. At the end of this chapter I will give you some experiments of this nature to perform.

Plants, like prudent housekeepers, have a careful eye on the distant future. We have already discovered that seeds are packed with food to which the young plants will help themselves when they germinate; and we have also seen that biennial plants, such as Carrots and Beet, and plants with underground stems, need a similar store to feed them when their new growth shoots up. This food, whether it consists of sugar or proteins, is prepared, wholly or partially, by the industrious green cells, passed on to the seeds and roots and underground stems, and there stored up in the form of starch or some other convenient substance until it is required by the new growth. Thus beetroots are packed with sugar, and potatoes with starch, while broad beans contain a large quantity of protein as well as starch.

These careful labours concern you and me, and all the other seventeen hundred million two-legged inhabitants of the globe, more closely than you imagine. It is from the foods stored up in the seeds, etc., not so much of wild plants but of plants expressly cultivated for the purpose, that we draw a supremely important part of our own nourishment. You have only to think, for instance, of the vast quantities of wheat (for flour and bread), oats, maize, rice and barley, of peas and beans, of potatoes, carrots, parsnips and turnips, that we consume every year to realise how generously we help ourselves to the varied products of the vegetable kingdom that it has amassed for its own private use.

And now I will carry you a step farther and tell you something that I think will stagger you. We derive from the plant-world *directly*, not only the foods I have mentioned, but also green vegetables, fruits, nuts, sugar, tea, and in fact every other item that appears on our table—except such articles as meat, fish, eggs and dairy produce, *i.e.*, milk, butter and cheese. But we derive from the plant-world *indirectly* these latter supplies as well; because the cows and poultry and other animals that furnish them to us are themselves nourished by grass and corn and other plants, or by the meat of other animals similarly nourished. Even fish is not excluded; for the bigger and stronger fish feed on the smaller and weaker ones, and the smaller ones gobble up those still smaller, and so on till you come to the smallest of all, which live on marine plants. Thus we arrive at the astonishing truth that we depend entirely—directly or indirectly—on the vegetable kingdom for the food that makes our existence possible.

Scientists are constantly experimenting in their laboratories with the ingredients that go to make sugar and proteins. They are trying to compound them into artificial foods in order to make us less dependent on natural supplies. They have scored a certain amount of success, but they find that what the plants do so easily is, in the main, beyond their own powers. To sum it all up: green plants can build up from the "raw" chemical elements existing in the air and the soil (carbon, hydrogen, oxygen, mineral salts, etc.) all the foods that living creatures (plants and animals, including human beings) need. Those same elements are as freely available to us as they are to the plants; but our bodies have no power to work them up into foods that we can digest, and our knowledge of chemistry has not yet discovered the way to do so. The secret still rests with the plants, and thus we can say that their green leaves are the food-factories of the world. So, if we woke up to-morrow to find that all the plants in the world had died overnight, we should soon be in a sorry plight. I think it makes plants extraordinarily interesting when you learn this tremendous fact and realise that every Buttercup and Daisy in the fields is silently carrying on its modest share of the complex work of food-manufacture; even though, in those particular instances, the products of their labours are not made directly available for us.

Even now I am far from having completed the account of our debt to the plants, for it is by no means limited to a mere matter of food-supplies. I daresay that by now you have quite forgotten the talk with my uncle which I narrated in Chapter I, so let me remind you of what he then told me. He said that plants supplied us, not only with food, for ourselves and our domestic animals, but also with clothes (for cotton is spun from the hairs on the seeds of the Cotton plant and wool comes from the backs of sheep, which themselves live on grass), furniture, building materials, medicines, paper, coal—and fishing rods and cricket bats. (Cricket bats are made from Willow trees that are carefully tended and felled from the age of twelve years and upwards. They grow best in England, and especially in the eastern counties; though I do not know whether the bat with which Don Bradman makes his frequent double centuries against us comes from one of our own obliging trees or from one growing in Australia.) Then I told you later about the various uses to which the fibres and bark of various plants are put. To all these items you may add such things as dyes, oils (coconut oil, olive oil, linseed oil), turpentine, perfumes, camphor, rubber, tobacco and a host of other useful or attractive materials that we could not well do without.

The Coco Palm

By this time you will have begun to form a fair notion of the manifold services which plants render to us; but, before we leave the subject, I think you would be interested to hear of a tree that merits special distinction as a sort of universal provider. This is the Coco Palm, which grows luxuriantly on those enticing tropical islands we read about with such longing in the voyages of the great explorers. The tree spreads all over the tropics, for the great nuts are carried by the sea for miles from shore to shore, the infant plants within them being perfectly protected by the hard shell. Practically every part of this wonderful tree is put to some use or other. The natives live largely on the nuts, and find them just as appetising as do our bright little blue-tits. The kernels contain a large quantity of oil (coconut oil), which we use in making soap and candles, as well as the more interesting items of biscuits and confectionery, and margarine. What remains after the oil is extracted makes a capital food for cattle. Indeed, I think they regard it as cake, while grass is merely bread and butter. In the tropics the oil serves also as lamp-oil. The rough fibres that clothe the shell are a most important article of commerce, being made into ropes and matting. I suppose there is scarcely a home in England that has not a doormat made of coconut-fibres. The shell itself is by no means valueless, for it is made into cups and goblets, often highly polished and richly carved, besides being put to the baser purpose of feeding the fire. The terminal bud of the tree is regarded as a great delicacy, and eaten as palm-cabbage, while the centre of the young stems is likewise devoured as food. The sugary sap makes a delicious drink. The dried leaves, which are sometimes a matter of twenty feet long, make excellent thatch for roofing, and they are also woven into mats, screens and baskets. Not only that, but the natives use the mid-ribs of the leaves as oars or paddles for their queer-shaped canoes. A kind of gum is obtained from the trunk and the wood is used for a variety of purposes. There are a dozen or two more ways in which the obliging tree renders service to man, but I think I have told you enough to justify my description of it as a universal provider—in which character it is an excellent representative of the plant-world as a whole.

You can go to the butcher for meat,
You can visit the baker for bread,
And Harrods sell all that you need, from umbrellas to cider;
But, whatever you purchase or eat,
Be it garments or pies or a bed,
Comes first from the Plants as the true Universal Provider.

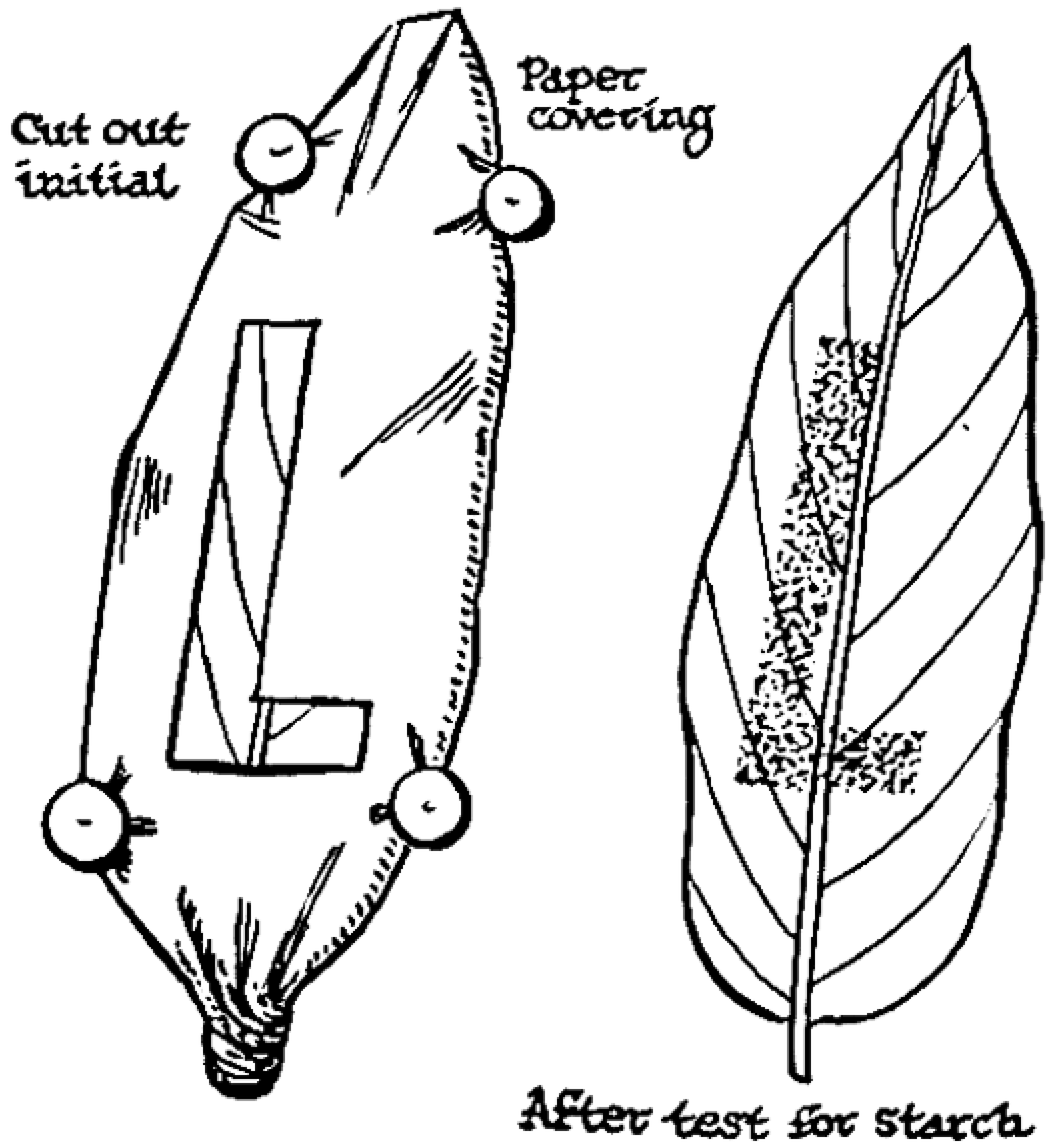
I have now revealed one of the ways in which the pores in the leaf and other organs serve a plant. A second way is connected with its breathing. We have discovered a good many features in which plants resemble animals, and breathing is another of them. Plants must breathe by night and day in order to live, and they do it in much the same way as we do, although they have not any lungs to help them. That is to say, they take oxygen into their bodies and give out carbon dioxide. In other words, they breathe in pure air and breathe out impure air. When a number of people are crowded into a room without sufficient ventilation, and the air becomes " fuggy ", it is because they are using up the pure oxygen and unduly increasing the impure carbon dioxide. In plants the oxygen enters mainly through the pores. It is then circulated through the plant by way of a system of air-spaces between the cells, and the carbon dioxide produced later passes out principally through the pores.

This brings us to what seems a contradiction. You have learned that, in the food-making process, plants take in carbon dioxide; but I have not yet mentioned that, as a part of that process, they also give out oxygen. In this way, then, they are purifying the air for us. In the breathing process, however, they are using up oxygen and giving off carbon dioxide—the very opposite of the other process—and thus making the air impure again. How can we explain these two opposite operations? And what is the final effect of them on the atmosphere? The answer is that, during the daytime, when both food-making and breathing are going on, the former operation is so much more active than the latter that it cancels it out. Plants, therefore, purify the air in the daytime. With the coming of night, however, we know that the food-factories, being deprived of the sunlight that keeps the engines going, close down, so that the only operation then carried on is that of breathing. Accordingly, plants must foul the air at night. The extent, however, to which they do this is quite trifling. The amount of carbon dioxide they release is insufficient to affect our health, so you need not follow the practice of some nervous people and banish plants from your bedroom at night.

Another lesson we may learn in connection with the breathing of plants and animals is this: The plants supply us with food and purify the air. On the other hand, animals and humans supply plants with much of the carbon dioxide needed for making food; for the former are constantly liberating that gas into the atmosphere in their breathing, as well as in other ways which I will not stop to describe now. They do, therefore, in some measure, repay their enormous debt to the plant-world.

I have told you a lot of important facts about the food-making activities of leaves, and I think now that you would rather enjoy making some experiments to confirm what you have learned.

In the afternoon of a warm and sunny day go out and pick a leaf, say of Clover, Geranium or Nasturtium; drop it into boiling water for a minute or two to kill it; and lay it in a saucer of methylated spirit. Presently the green chlorophyll will begin to dissolve out, and in time the leaf will become colourless. Rinse the leaf and pour some weak iodine solution over it. It turns dark blue—and you know by now that that indicates the presence of starch. The leaf has been actively accumulating starch, as I explained on p. 78.

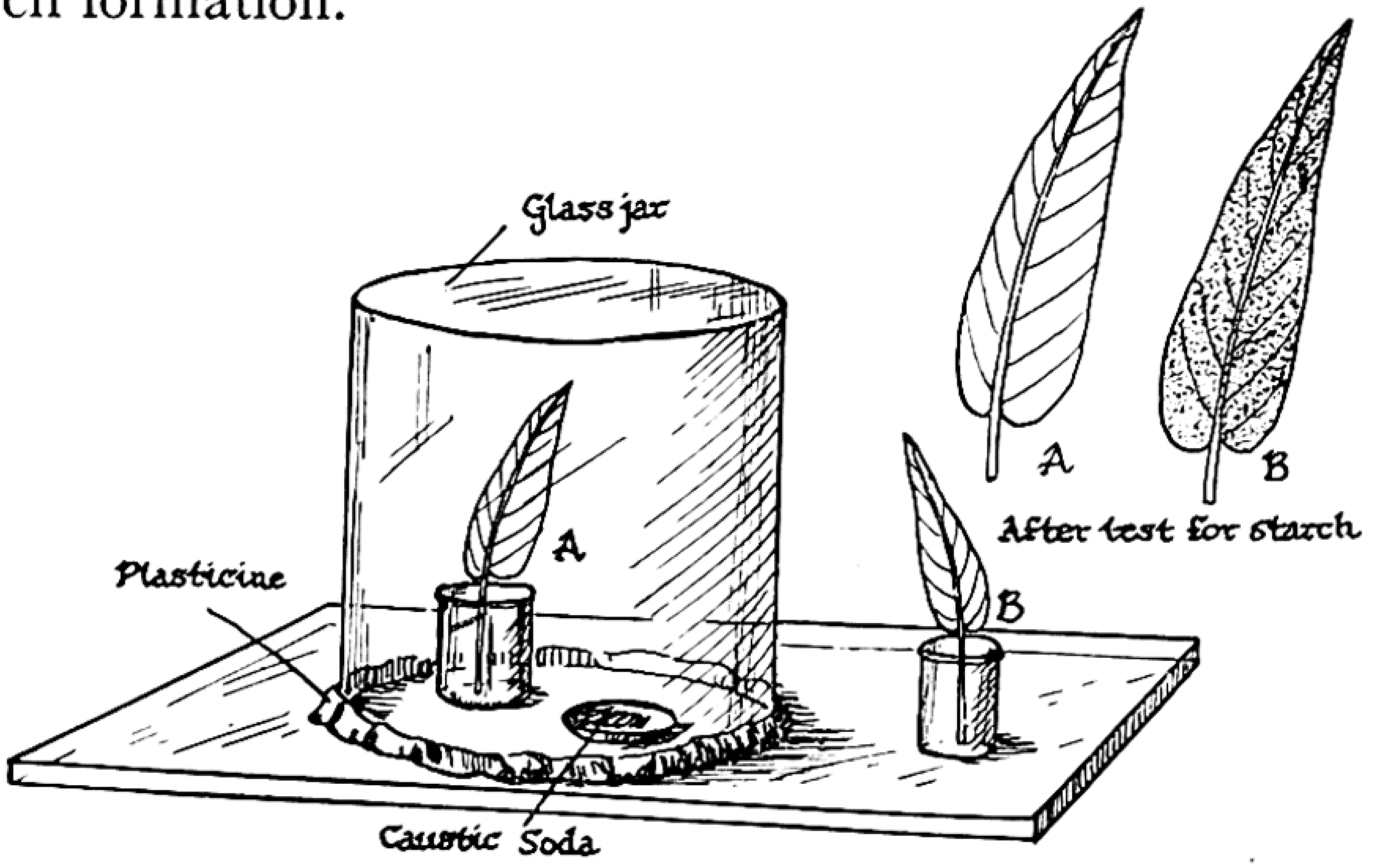


Demonstration of Starch Manufacture by Leaf

Now repeat the test on a variegated leaf of Geranium, first making a drawing of the leaf in which the green and the non-green parts are indicated. Compare the result with your sketch, and you will discover that starch appears only in those parts of the leaf that were coloured green. These are the only parts that contained chlorophyll, so I think the inference is obvious (see p. 76).

For the next three experiments you will need pot-plants, and these must first have been placed in a dark cupboard for two days, during which time the leaves will have emptied themselves of starch.

Cut a cork into two rounds and pin them opposite each other on the upper and lower sides of a leaf, leaving the latter attached to the plant and placing the plant in sunlight. After five or six hours pick the leaf and test it for starch. You will discover that there is none present in the circle that was covered by the cork. A more entertaining experiment is to cut out your initials from a piece of tinfoil or black paper, fold it closely round a leaf, back and front, with the initials uppermost and pin it securely round the edges. When you test for starch your initials will stand out in blue against the pallid background of that part of the leaf which was covered by the tinfoil. Refer to what I said on p. 76, and consider whether these experiments show that light is essential to starch formation.



Experiment showing Necessity for Carbon Dioxide

Now pick two small leaves from a plant taken from the dark cupboard and place them with their stalks in small jars or glasses. Stand one jar on a glass plate with a watch-glass, or other small vessel, containing a few sticks of caustic soda beside it. Cover them with a bell-jar, or some other large glass jar, and smear the junction of jar and plate with vaseline or plasticine to make it quite air-tight. Stand the apparatus, and the small jar containing the other leaf, side by side in a good light (but not in the sun) for several hours. The point to be realised is that the leaf imprisoned under the bell-jar will be deprived of carbon dioxide because the caustic soda will absorb it all; while the other leaf will have access to the free carbon dioxide of the atmosphere. After several hours test the leaves for starch, and you will find none in the imprisoned leaf. Refer to p. 75, and see if you can account for this.

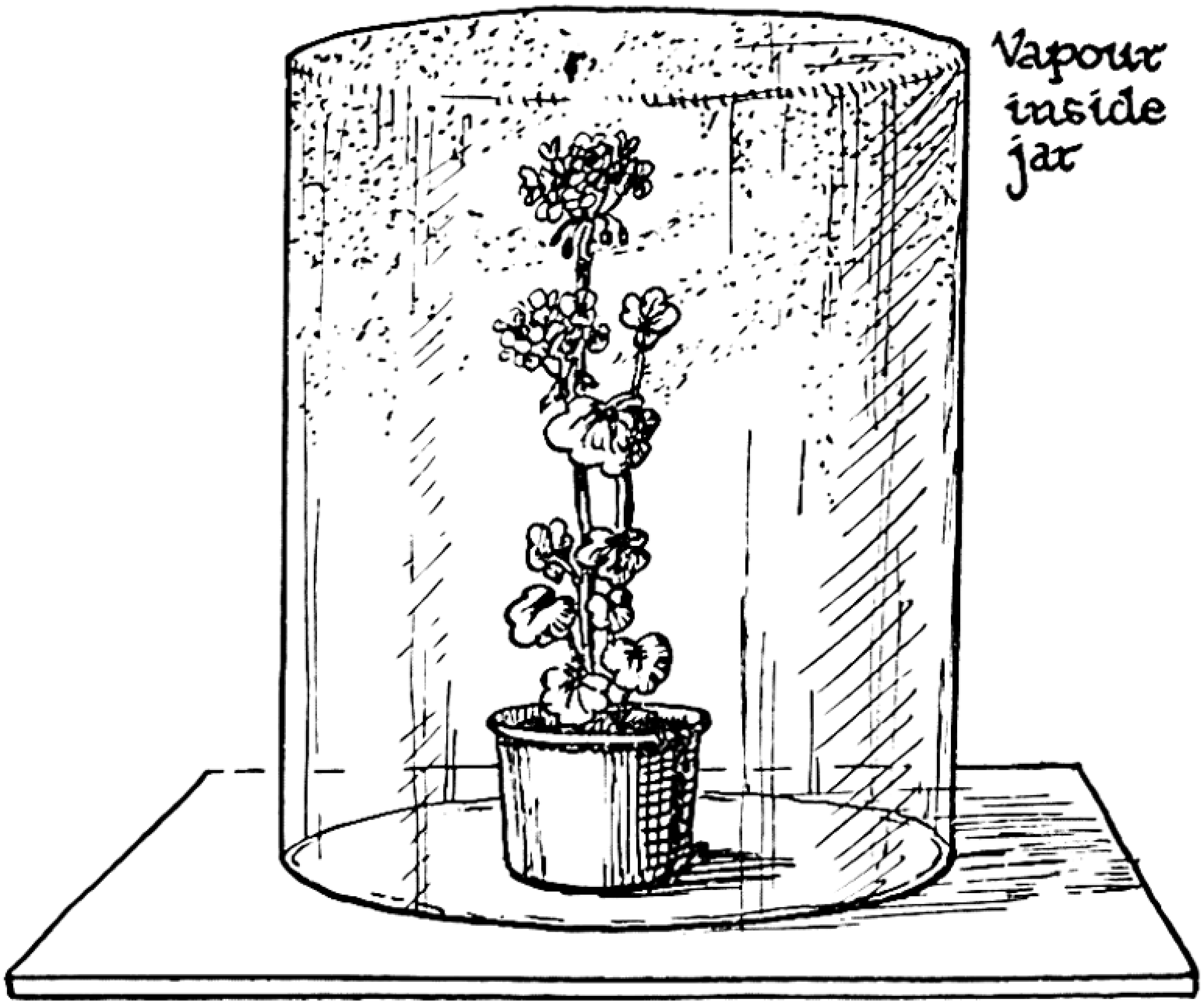
CHAPTER VIII

FURTHER ADVENTURES AMONGST LEAVES

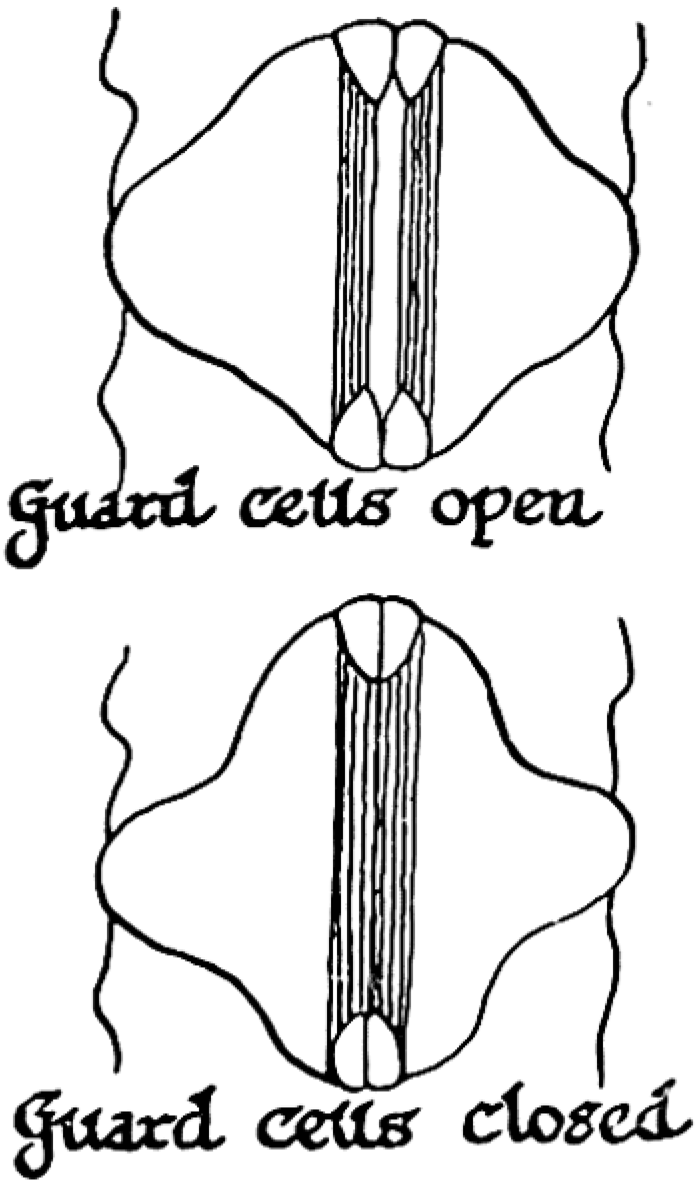
WHEN Uncle Fred was explaining the work of the leaves he took a Geranium growing in a pot, stood it on a glass plate and covered it with a glass jar. After some time we saw that the inside of the jar had become clouded with a film of vapour. You will remember that the roots of a plant are constantly sucking up large quantities of water and dissolved mineral salts from the soil and sending them up the stems through the water-pipes. They have to deliver their supplies copiously, partly because the plant can only use the salts in a very weak solution, and partly because the cells need an ample supply of liquid to keep them taut. Sooner or later, however, the plant finds that it has a great deal more water than it knows what to do with, and so it disposes of the surplus by discharging it into the atmosphere, mainly through the pores in the leaves, etc., in the form of vapour. You cannot actually see the vapour issuing, but we did see it when it had condensed on the inside of the glass jar. In the chapter on the Root I mentioned that the leaves, in giving out this water-vapour, exerted an upward " pull " on the sap, and so helped to account for its rising. You will appreciate the tremendous strength of this force when I tell you that a Sunflower plant, or a Cabbage, may give off a pint and more of water in the course of a summer's day and a Beech tree nearly a hundred gallons, while an Oak may liberate over two hundred *tons* in the course of a summer. The discharge of water-vapour is greatly reduced at night, which gives the cells an opportunity to fill up again if they have been drained by a hot, dry day.

You will now have gained an idea of the importance of the pores in the leaves, etc., of which I have said so much, and I think you will be interested to learn of a rather neat piece of mechanism with which each one is fitted to increase its usefulness.

It makes it rather like a mouth. On either side of the pore or mouth is a curved cell like a lip, and these two lips have the power of drawing together and closing the mouth when occasion requires. Speaking generally, the lips close, or almost close, about sunset, when the food-factories stop work. With the rising of the sun the factory-engines are ready to restart, and the lips are again opened. So, too, if, during the daytime, the plant is losing water faster than the roots can replace it, the lips will tend to close before the loss becomes fatal, and remain so until the supply is replenished. The usefulness of the guard-cells, as they are called, is greatly increased by the fact that the skin of the leaves is thickened with a material that makes it more or less air-proof and water-proof. Most of the air and water must, therefore, pass through the pores, and so the guard-cells are in a position, in a great measure, to regulate the supply in accordance with the needs of the plant. The pores, none the less, do not close sufficiently tightly to stop the plant's breathing. Moreover, breathing, and also the discharge of water-vapour, can take



DEMONSTRATION OF LEAVES TRANSPIRING WATER-VAPOUR



A LEAF-PORE WITH GUARD-CELLS OPEN AND CLOSED place to a certain extent through the general surface of the skin.

One autumn day my uncle took Janet and me for what he called a " crawl " in the woods. As his normal pace was well over four miles an hour, I never thought the word altogether apt, and for us the " crawl " was usually more of a trot. That day, I remember, a gale of wind was blowing and the leaves were simply whipped off the branches and sent flying helter-skelter.

" Remember the story of the walking leaves they found on Magellan's voyage? " called out my uncle.

" No," we said, and sprinted to catch up with him, expecting a story.

" It was old Pigafetta who told it. You must remember him. He sailed with Magellan to see the very great and awful things of the ocean, as I believe he called them. When they got to Borneo, Pigafetta declared he'd seen some trees whose leaves fell to the ground and made off on a pair of feet if you touched them. He put one of the leaves in a box and kept it for nine days and, when he opened it again, the leaf was walking round it."

" What a yarn! " I exclaimed.

" Well, it *is* rather, isn't it? but Pigafetta can be forgiven for his mistake. The leaves weren't leaves at all, but insects that camouflaged themselves to resemble the leaves they fed on. A safety-first device to make them less visible to their enemies."

As we hurried on through the whirling leaves, thinking of poor, gullible old Pigafetta, Janet suddenly burst out: " Isn't it a shame? I do wish the leaves were stuck on tighter, so that they could stay on all the winter. The poor trees look so bare and dead."

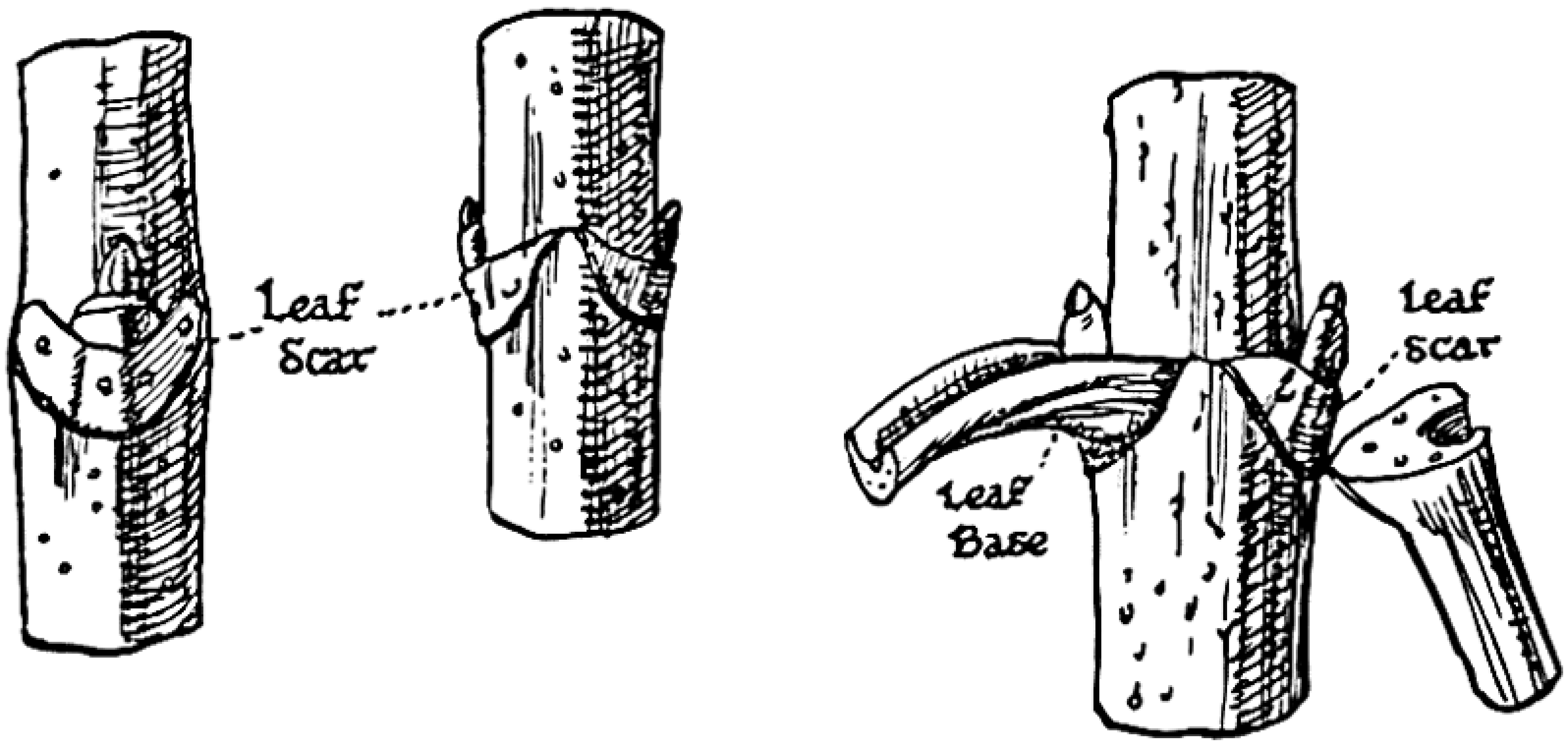
" What about the evergreens? " asked Uncle Fred with a smile.

" Oh! but they're so stiff-looking—Pines and Firs and Holly and—— But still—Uncle, how is it *their* leaves don't get blown off? "

" Let's go and look at some—Pines and Holly, and the Beeches and Oaks as well—and see if we can find out."

We spent the whole afternoon over it and, while we were " walking " back home, Uncle Fred explained heaps of things about them that we'd never thought of. What he told us was this:

The autumn leaf-fall safeguards the tree from the danger of drying up during the winter. During that season the soil often becomes so cold that the roots can absorb only a little water. If, then, the leaves (which, you will remember, are constantly giving off water-vapour) were allowed to remain on the trees, the latter might be in danger of drying up. The leaves, for various reasons, couldn't check the passage of the vapour all the time. So the tree takes steps to get rid of them in good season, and this was where Uncle Fred gave us a surprise. He said it was a mistake to regard the autumn leaf-fall as a violent robbing of the trees by the gales. You might just as well believe the old nursery tale that the elves flew away on the falling Oak leaves. The leaves had done their work for the season, and now they must be discharged. Accordingly a layer of special cells is formed right across the base of each leaf-stalk where it joins a twig, and the supply of water is cut off as if the water-rate hadn't been paid. The condemned leaf then hangs by a few threads, which are, in fact, the wood- and bast-bundles, and these are easily broken. The layer of separating cells becomes corky to protect the wound caused by the break, and it is these corky layers that form the leaf-scars you see on the twigs, the snapped veins often showing clearly as so many dots.



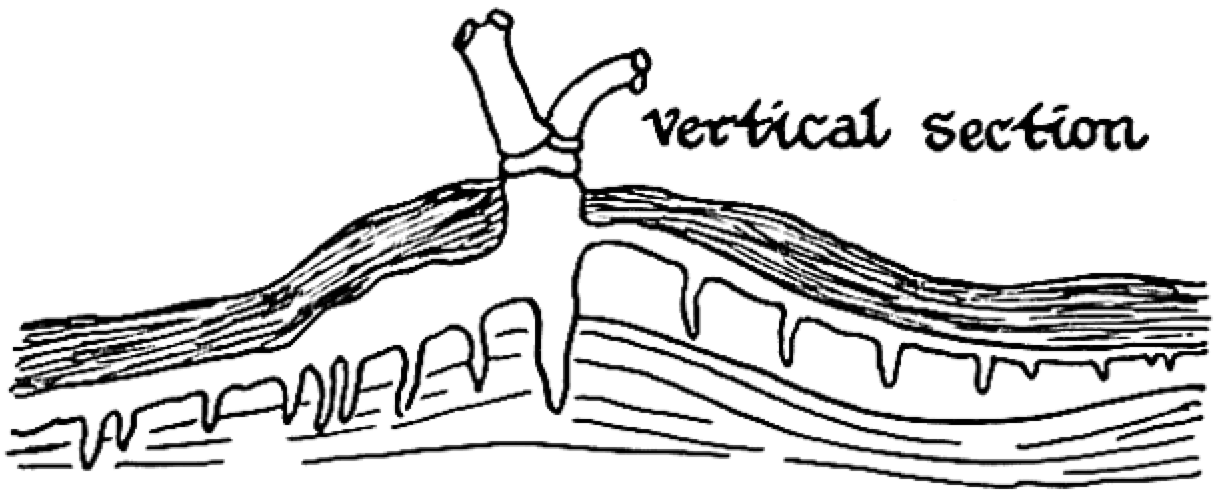
LEAF-FALL, SHOWING LEAF SCARS AND YOUNG LEAF BUDS

But how, you will ask, do the evergreens avoid the danger of drying up? Well, they do it in various ways. Most of them, you will notice, have extra thick, leathery skins. Others show, under the microscope, that the pores are sunk in pits or grooves, so that the vapour collects there in a tiny invisible cloud and checks the outward flow. Hollies furnish examples of both these clever devices. In Pine trees and other plants the leaves, being needle-like instead of broad and flat, have only a very small surface from which the vapour can escape. These and other adaptations all serve as checks on the escape of vapour and reduce it to a minimum.

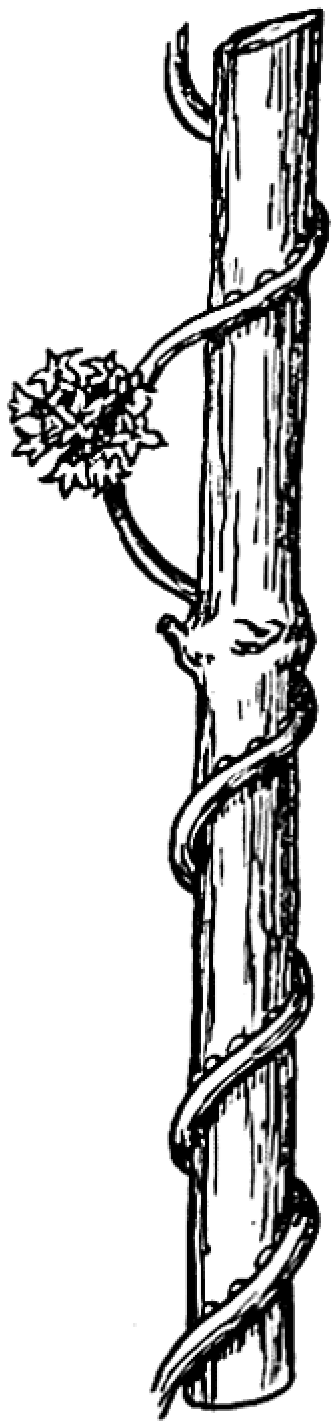
Trees that shed their leaves in autumn may be likened to animals that curl up and go to sleep for the winter. It is what people call the dead time of the year, but the trees are very much alive. You have only to look at the buds studding the branches (about which I told you in the last chapter) to see that, before going to sleep, they made full preparations for a new burst of activity as soon as the spring should awaken them with its glad summons to be up and doing.

Although the members of the great society of flowering plants are, as a whole, industrious and largely self-supporting individuals, there are, I am sorry to say, a number of them who have fallen into bad habits. Some have merely grown a little slack, but others can only be termed idle rogues. These last have ceased, either wholly or partially, to cater for themselves and become more or less dependent on other plants for their food-supplies. Such idle plants are called "parasites" and the unfortunate plants on which they fix their tentacles are called the "host", although it is hardly in that sense that we speak of our hosts and hostesses at a party. It is a regrettable fact that the pretty little Eyebright, the Cow-wheat, the Yellow Rattle and some other flowers that ornament our meadows are included in this undesirable company. These plants fix their rootlets on to the roots of the neighbouring grasses by means of suckers, and so tap the liquid supplies of the hapless host. They have not, however, gone altogether to the bad, for their leaves do make *some* food.

The Mistletoe, to which we accord such a prominent place in the Christmas decorations, is a parasite of curious habits. It never grows in the soil, but, as if asserting its social superiority over the common rabble of the plant world, germinates high up in the cracks of branches of Apple and other trees after the sticky berries have been carried there by birds. The ancient Druids, about whom you read in history, held the plant in the greatest awe. They thought it must be of a sacred character, perhaps because of its lofty situation, and they accordingly credited it with magical powers. The superstitious veneration of the plant has been a long time in dying out, for there is a tale of much later times about some Mistletoe plants that were cut down from an Oak tree to be used by the chemists as medicine. The legend says that all the men who took part in the work became either lame or blind in one eye! Well, this greatly honoured plant sends its roots deep down into the branch and freely draws on the tree's supplies, though, like the meadow-plants I mentioned just now, its green leaves are not idle.



Mistletoe Growing on Branch of Tree



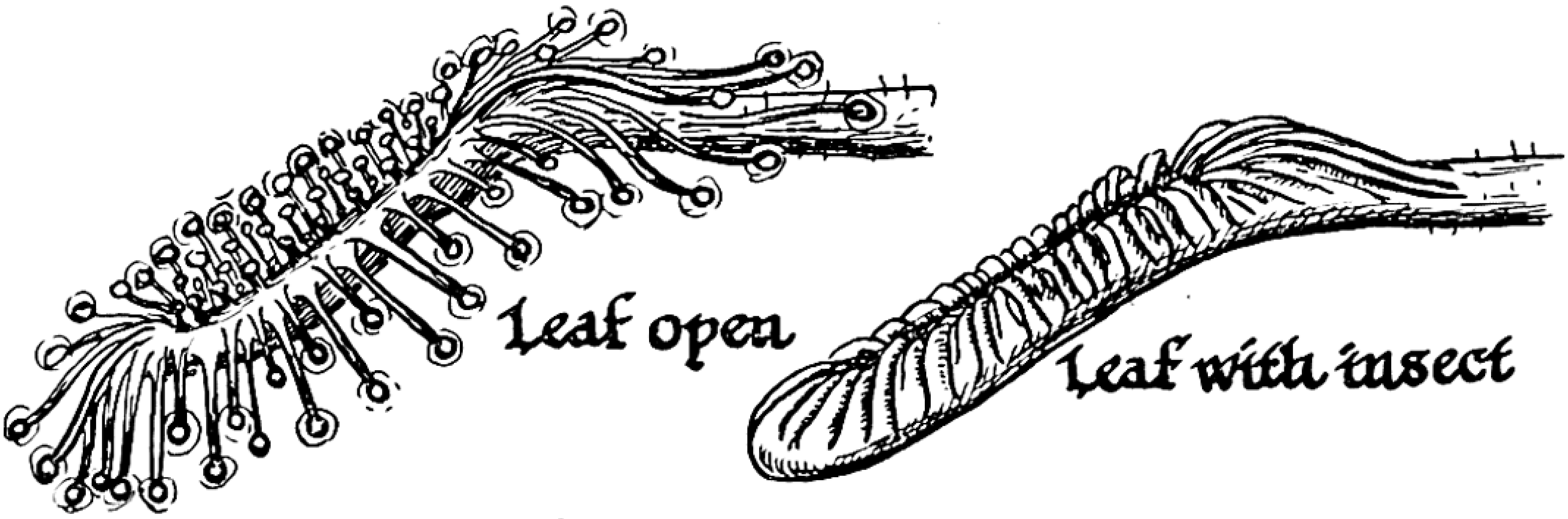
The Parasitic Dodder

But the lowest depths of infamy are reached by such plants (happily there are only a few of them in our country) as the Dodder. These have simply given up the arduous work of food-making altogether and learned, like so many tramps, to live on the community. The Dodder is an exquisitely dainty little growth that twines its delicate, flower-set threads round the foliage of the Gorse, Clover and other plants like a necklace of jewels. It is a pity that its outward beauty is so completely out of accord with its habits. The fine threads wind themselves around the host-plant, and, by means of the suckers which they bear, the worthless parasite sucks in the whole of its food ready-made without doing a hand's-turn to earn it.

Even great forest-trees such as Beeches and Pines, although they are really not parasites, depend on other growths for part of their sustenance. The roots of these lordly giants produce few or no root hairs, and so they cannot absorb water and mineral salts in the normal way. Instead, they rely on a kind of fungus to perform the office for them. These lowly plants spread a mantle of fine threads about the younger roots of the tree. They absorb water and mineral salts from the soil, and probably also extract ready-made food from the decaying vegetation there, and these pass into the roots of the tree. The fungus-plants doubtless receive certain benefits in return for their services, probably being permitted to enjoy a humble share of the great store of food manufactured by the leaves of their very superior employers. This is one of the strange partnerships for mutual benefit you often find in Nature; and, like the fable of the lion and the mouse, it shows how the smallest things may be of service to the great.

Plants have the happy knack of making the best of their surroundings, often with surprising results. In sour and boggy soil, or watery places, you may chance upon a small brotherhood of plants that have learned to devour living animal food. Their watery home fails, apparently, to furnish them with the necessary nourishment, so they have developed a means of making good the deficiency. They trap insects and feed on them. One of these plants is the Sundew. Its round or oval leaves are set with long hairs or tentacles that swell out into a knob at the end. The knob is coated with a drop of glistening gum. A flying insect sees it. It settles on what it fondly imagines to be a rich dish of honey—and its fate is sealed. The sticky gum holds it fast, the tentacles bend slowly but surely inward and the struggling creature is held tightly against the surface of the leaf while the juices of its body are absorbed as food. After perhaps a day or so, when the unlovely work is done, the tentacles open out again and the hungry plant is ready for another victim. The uncanny thing is that it seems able to tell whether any object settling on its tentacles is good to eat or not. If you drop particles of dust or fine hair on the tentacles you can persuade them to close over them in time, but they begin to return to their normal position when the plant discovers that it cannot digest them. Try the leaf, however, with a morsel of raw meat or white of egg, and the tentacles will retain their grip on it until it has been absorbed, even if it takes a week to do it.

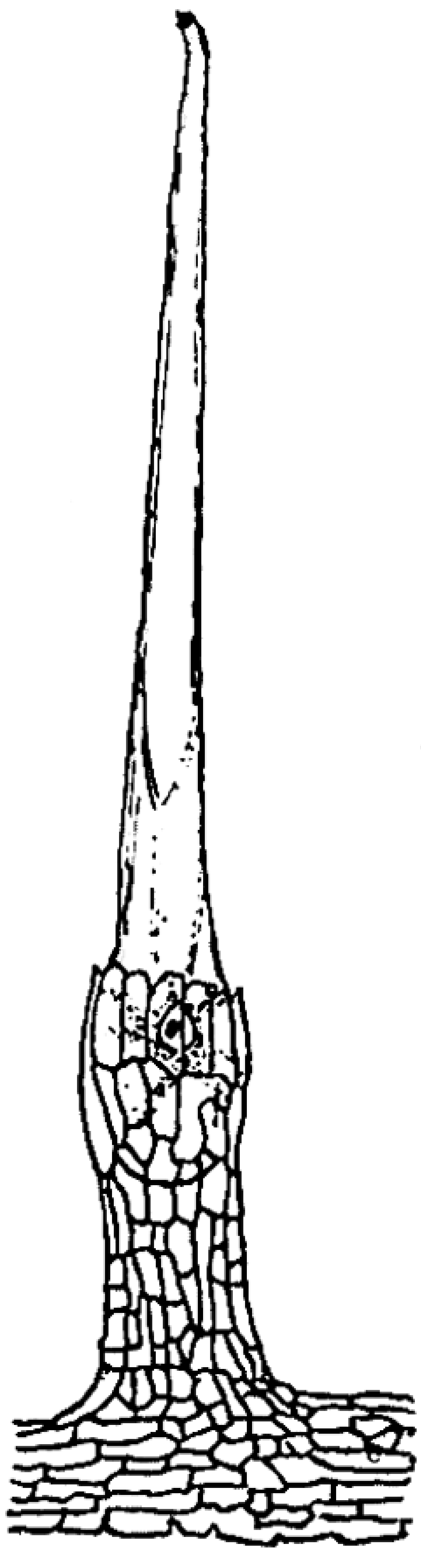
That is rather a gruesome subject, so I think we will pass on to something else. I daresay you have sometimes wondered why the leaves, and also the stems, of plants are often so hairy. Look at the Mullein: the leaves are so densely clothed that they feel like so many blankets. In the country, people do, in fact, call the plant by such names as Blanket-leaf, Flannel-flower and Poor-man's-flannel. Well, you might say that such hairs *do* act as a blanket, though it isn't intended for human beings, but for the plant which incurred the labour of producing them. The blanket no doubt serves to keep the plant warm on cold nights, but its chief use seems to be to prevent water-vapour from escaping too freely. The hairs do this by retaining a good deal of the vapour around themselves and so forming a damp covering (or wet blanket) for the leaves. Hairs also help to moderate intense light and heat that might injure the delicate and priceless chlorophyll, for, like all living creatures, plants suffer from extremes of cold and heat.



Sundew trapping Insect

Some hairs secrete peculiar liquids that make the foliage distasteful to animals and thus effectively discourage them from making a meal of it—which seems quite a reasonable thing for the plant to do. In this and other ways a coat of hairs becomes a coat of armour as effective as the mail which knights put on in olden days to safeguard *their* persons from danger. The most familiar instance of " defensive " hairs is that of the stinging-hairs of the Nettle—a plant which a rather crusty old writer unnecessarily informs us " may be found *by feeling* on the darkest night." You know how severely the plant punishes you if you do " feel " it. But do you know how the punishment is administered? When you are so unwary as to touch a leaf, the swollen tips of the hairs break off, leaving a needle-like point. A little bladder, cunningly situated at the base of the hair (which is hollow) suddenly contracts, and the acid juice it contains is injected smartly into your offending hand as the needle-point pierces the skin. I think we may salute the Nettle, dour-looking and unsociable though it may be amongst the happy company of the hedge-banks, for devising one of the most ingenious and successful means of self-defence in the plant world.

Nowadays we have forgotten the old romantic associations of leaves, and given our admiration mainly to the flowers of a plant. Leaves are gathered chiefly as commonplace and unexciting articles of food or medicine. We eat them as vegetables or salads. We put them into stews and other dishes for flavouring. We extract useful medicines from them. Or, with a slightly less practical motive, we preserve them for the perfumes they exhale. But in the times of the ancient Greeks and Romans the leaves of many trees and lesser plants were very differently regarded. Trees such as the Olive, the Oak, the Myrtle and the Laurel were looked upon as sacred; for they were under the special protection of one or other of the great pagan gods, and as such were invested with mystic powers. Their leaves were woven into chaplets to deck the brows of poets, or of heroes returning from the wars, or of the victorious athletes in the splendid public games. In some


STINGING HAIR OF NETTLE (HIGHLY MAGNIFIED)

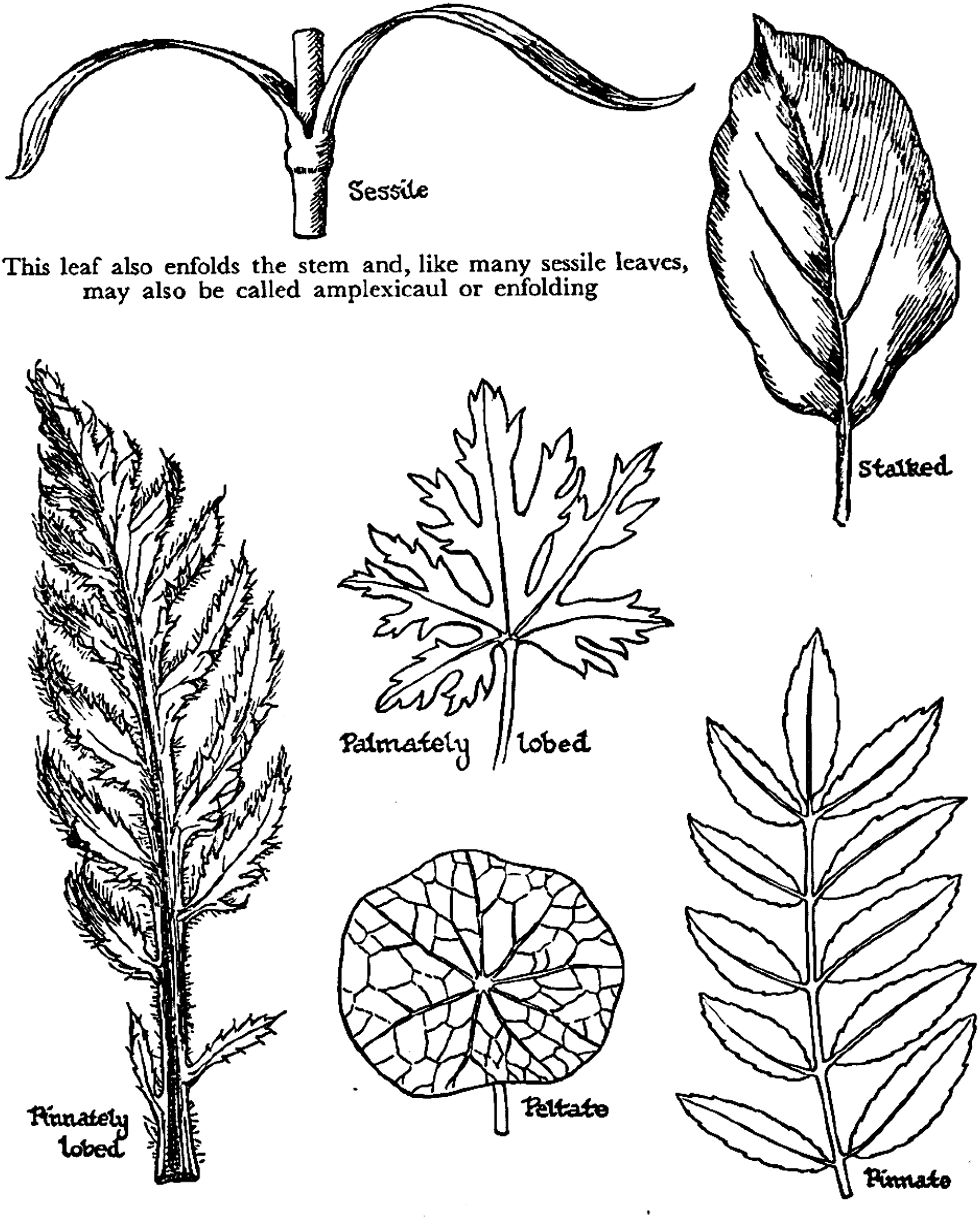
countries leaves were supposed to know all the secrets of the past, present and future. Ancient magicians, when they pretended to foretell the future, wreathed their brows with chaplets of leaves because they believed that the secrets they held would thus be revealed to them. In our own country there was a time when the great ladies of the Court thought it not unbecoming to deck their head-dress with the feathery foliage of the humble Carrot, deeming it a graceful substitute for the plumage of birds.

I suppose we must not interrupt our studies too long to dwell on these old practices, but I think I may be allowed to tell you a story that is more closely connected with them. It is the story of the silkworm. You know, of course, that it is from the cocoons of the silkworm that we obtain silk, and probably you know also that the natural food of the insect consists of the leaves of the Mulberry tree. Well, I suppose there have always been Mulberry trees in Europe, but there was a time when there were no silkworms. In fact, the few fortunate people who could afford to wear silken garments had only the vaguest notion of how the lustrous material was produced. Many of them thought that silk grew on some foreign tree; most of them had learned that it came from far distant China; and all of them were aware that it was exceedingly scarce and worth its weight in gold.

That was how things stood up to about fourteen centuries ago. Then it happened that two Persian monks, who had lived a long time in China and learned the secrets of the industry, arrived in the city of Constantinople. The Emperor Justinian heard of the tales they told of the rearing of silkworms and the production of the priceless thread, and he was filled with a great longing to possess some of the profitable insects. So he summoned the monks to an audience and begged them to return to China and bring him some silkworms so that he might establish the industry in his own land.

The monks looked at each other rather doubtfully. "It would be a difficult and dangerous undertaking," they told him. "The Chinese guard the secrets of the industry very jealously, and they would assuredly chop off our heads if they caught us."

Well, that was rather a depressing response, but the Emperor, who was accustomed to having his own way and whose head,



This leaf also enfolds the stem and, like many sessile leaves, may also be called amplexicaul or enfolding

LEAF-FORMS

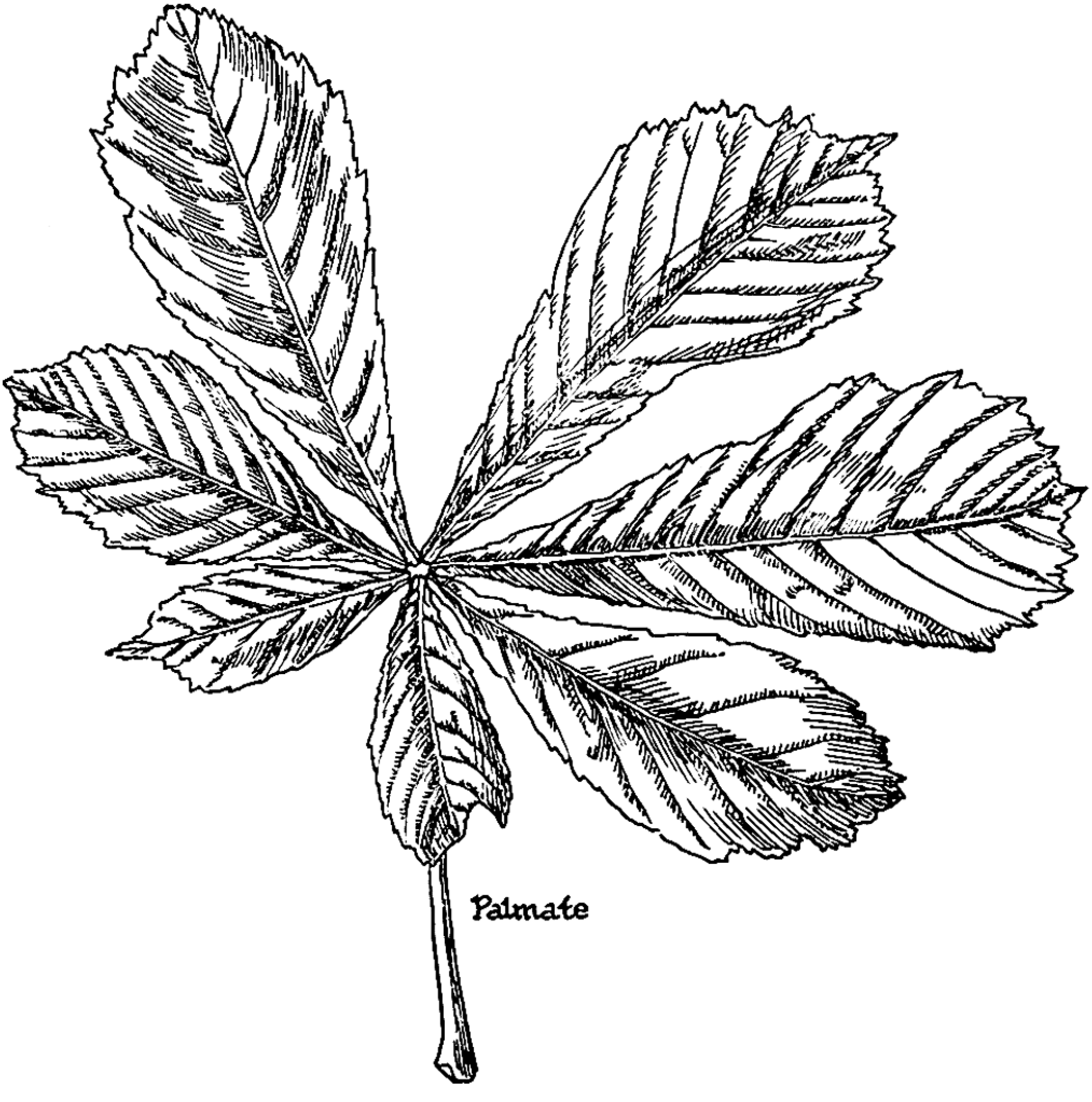
at any rate, would not be in danger, continued to exhort the monks, until in the end they promised to make the attempt. So the pair set off on the long and perilous return journey to China. Arrived there, they managed to secure some silkworm-eggs, and eventually they smuggled them out of the country by concealing them in a hollow cane. Then once more they set out to cross the whole continent of Asia, and at last, after encountering many perils by the way, found themselves back in the city of Constantinople—much to the satisfaction of the Emperor. There the eggs were hatched out and the caterpillars fed on Mulberry-leaves, and that was the beginning of the industry in Europe.

Anyone can breed silkworms if they obtain some Mulberry leaves, and fascinating creatures they are to rear. Mulberry trees have been planted in various parts of England, and Janet and I used to buy the leaves from a little old herb-woman at twelve a penny, though twelve didn't last the gluttonous little creatures long.

Before we conclude this chapter I think you ought to have a short lesson on the shapes and other features of leaves and the names which distinguish them, because these will help you to identify plants from their descriptions in books. You will not remember all of them at once, but you can master a few at a time as you find the different types of leaf.

When a leaf is without a stalk it is said to be *sessile* (which is derived from a Latin word meaning "sitting"), because, I suppose, the leaf sits on the stem instead of standing on it on one leg. A leaf divided into distinct portions, or *leaflets* (as in the Common Ash and the Horse Chestnut), is a *compound* leaf; otherwise it is *simple*. A compound leaf may be either *pinnate*—*i.e.*, feather-like—or *palmate*. In the pinnate leaf the leaflets (which often look like separate leaves) are set on either side of the mid-rib, sometimes with, and sometimes without, an odd leaflet at the end, as in the Common Ash. In the palmate leaf the leaflets all radiate from one point, as in the Horse Chestnut. A simple leaf that has its edge, or margin, more or less deeply cut, yet not so deeply as to divide it into separate leaflets, is said to be *lobed*. If the lobes approach the pinnate form, it is *pinnately lobed*; if the palmate form, it is *palmately lobed*.

Some of the more common shapes of leaves are shown in the illustrations, together with the names attached to them. In addition to these, leaves are often described simply as "oval," "oblong", "elliptical", "orbicular" (circular), etc., when they tend to resemble those figures. Round leaves whose stalks join the blade underneath near the centre (as in the Pennyworts) are described as *peltate*, or shield-like. You will discover in actual practice that leaves do not by any means always accord



PALMATELY COMPOUND LEAF OF HORSE CHESTNUT with the shapes I have mentioned, but that there are numerous intermediate forms.

The margins of the leaf-blade also have been given descriptive names, some of which I will mention. An even, uncut margin is *entire*. When it bears forward-pointing teeth, like a saw, it is *serrate*. If the teeth stand straight out it is *dentate*, or, when they are rounded, *crenate*.

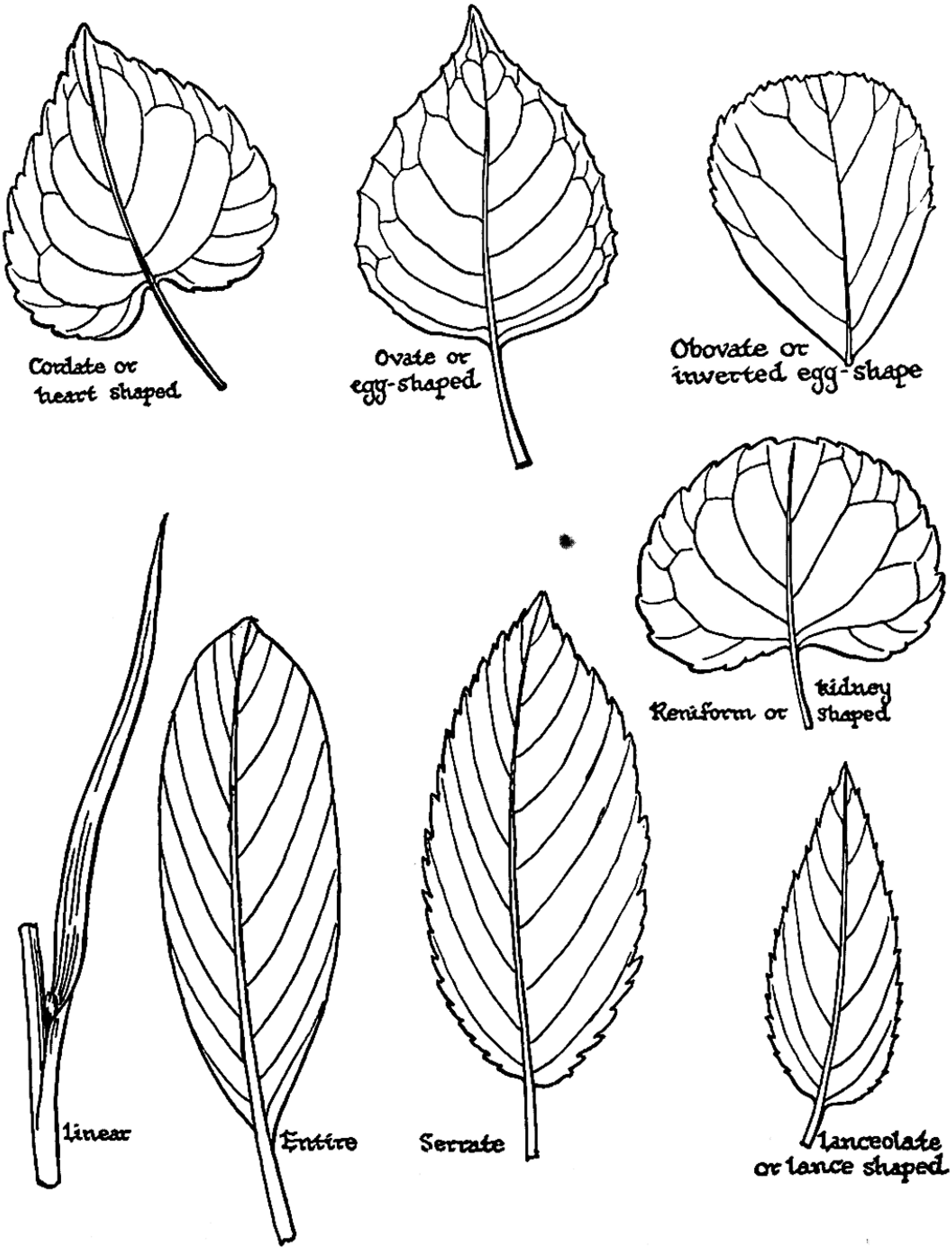
The surface of a leaf may be *hairy*, *glabrous* (without hairs) or *glaucous* (with a bloom.) Additional terms are used, but I do not think you need learn them at present.

Now I think we are entitled to hear some rhymes Janet has written about the feeding habits of plants. I can't say that they do her much credit, for they show which way her mind was running when she ought to have been studying the subject seriously.

It sounds jolly good
To be swallowing food
From the time that you turn out of bed,
To do nothing but munch
Till dinner or lunch
And on till the tea-table's spread,
And not to be beaten
Till supper is eaten
And slumber attracts you, full-fed.

And, if I mistake not,
That's the fortunate lot
Of the trees and the humblest wild flower;
For, wherever they stand,
Both the air and the land
An abundance of food-supplies shower;
And their appetite's such
That they *can't* eat too much
Though they've millions of mouths that devour.

Through the leaves they let pass
A most savoury gas
Which yields them the carbon they prize,
While the roots are officious
To send up delicious
Rich salts in unfailing supplies;
And there's oxygen relish,
The feast to embellish,
And hydrogen good as mince-pies.


Cordate or heart shaped
Ovate or egg-shaped
Obovate or inverted egg-shape
Reniform or kidney shaped
linear
Entire
Serrate
lanceolate or lance shaped

Leaf-shapes and Margins

So we're bound to agree
That they have a great spree
For all that their lives seem so quiet.
And yet I must say
That their menu each day
Offers rather a limited diet:
Just proteins for meat
And plain sugar for sweet
In the schoolroom would soon cause a riot.

Still the plants are satisfied
And happy as a King,
For listen to the chorus
Of the merry song they sing—
"Hydrogen and oxygen
Are very nice for tea,
And lots of lovely carbon
Is good for you and me.
There's nothing like some proteins
To make our spirits glow;
Besides, the more we eat and drink,
The faster we shall grow."

When you perform the experiment on *transpiration*, as it is called, described on p. 85, you will need to wrap some tinfoil round the pot, and arrange it so that it covers the soil, in order to prevent evaporation from those sources. You must also make the joint of the jar and plate air-tight.

A very simple transpiration experiment can be made with various kinds of leaves—*e.g.*, Clover, Nasturtium and Ivy. Pick three leaves of the same plant; smear vaseline on the upper side of one, the lower side of the next and both sides of the third. Seal the ends of the stalks with vaseline, hang up the leaves with thread and observe the order in which they wilt through loss of water. The first-mentioned leaf will suffer first, then the second and finally the third. This is because the pores through which mainly the leaves transpire have been closed by the vaseline—the whole of them in the third leaf, those on the (lower) side where they are usually most numerous in the second and those on the (upper) side where they are usually fewer in the first (see p. 74).

I need hardly tell you what attractive patterns are to be found in leaves. Draw those you discover from day to day, and show both their outline and the arrangement of the veins.

CHAPTER IX

FLOWER-PARENTS AND THEIR CHILDREN

I THINK we are getting on famously with our studies, for now we have reached the flowers. The workaday leaves, toiling industriously all day long without any holidays to look forward to, are left behind, and we turn now to those crowning glories of the plant that seem to be borne only to beautify the world and which form indeed for us the plant's outstanding attraction.

Doubtless you are prepared for the question I have waiting for you—What are the flowers for? And, surely, you will say, it's easy enough to answer *that*? Indeed, you have already suggested the answer yourself. The flowers bloom to make the countryside beautiful for us. They fill the fields and hedges with glowing colour, and the air is laden with their delicious odours. What would the countryside be without them? No Honeysuckle or Roses to deck the hedgerows; no Meadowsweet to perfume the summer air in the wet pastures; no happy multitudes of golden Buttercups and shining Daisies to paint the meadows with their brilliant hues—it is unthinkable!

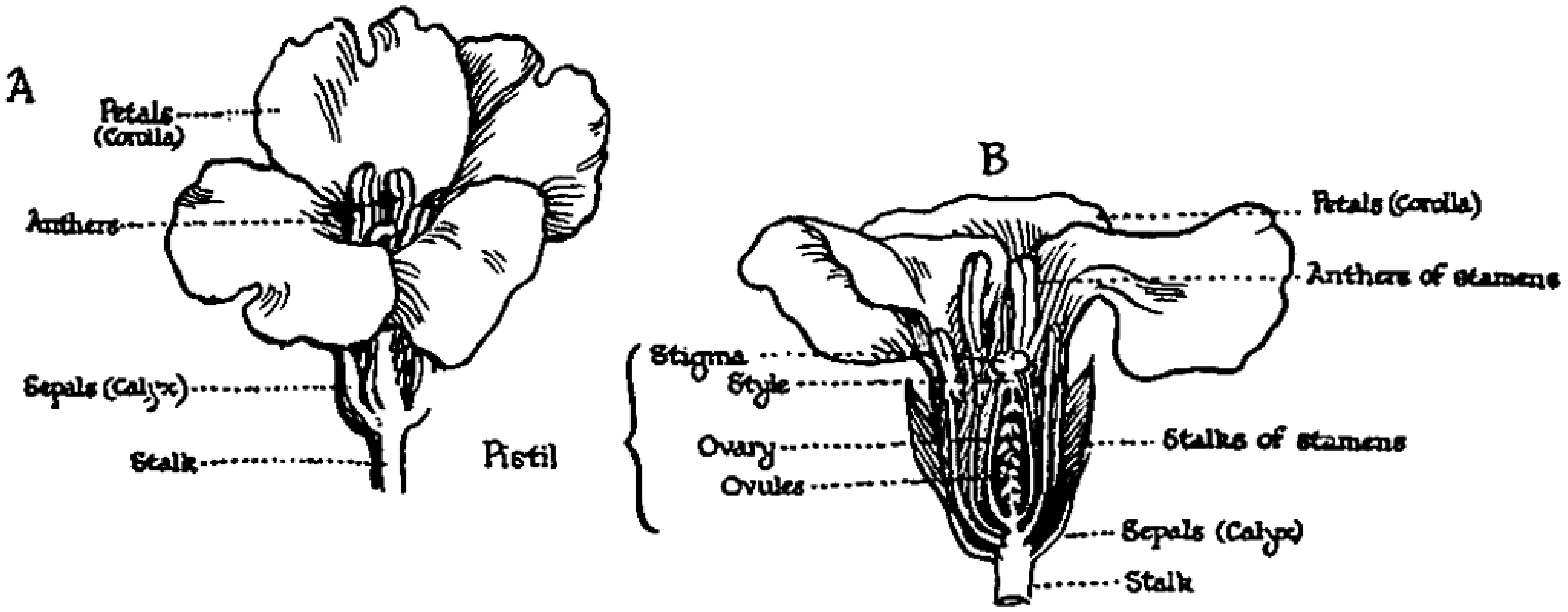
Well, and so it is; but—aren't you rather considering the question from your own point of view, instead of from that of the plant's? The flowers do indeed charm us with the rich feast of beauty they so lavishly display, and it would be pleasant to feel that, in so doing, they gained a sufficient reward. But you have learned by this time that every organ of a plant has its own special duties to perform for the welfare of the plant itself, else it would not be there. What duty, then, of this character does the flower perform? The answer is that it produces the seeds which carry on the race. A moment's thought will satisfy you that this is the highest of all plant functions. Without seeds the greater part of the world of flowering plants would necessarily come to an end, just as we human beings would come to an end if no more babies were born. It is true that many plants reproduce themselves by means of tubers and bulbs and corms and other stems, both underground and above ground; but the more general and advantageous rule is to rely upon seeds brought forth by the flowers. The flowers, then, are the parents of the seeds. Their attractive hues and rich perfumes, and the sweet nectar and golden pollen they produce, are means of ensuring, in a manner which I am going to explain, that the plants, through their offspring, shall never disappear from the face of the earth. That is the real object of the flowers, and it is simply a piece of great good fortune for us that they should achieve it by such attractive means.

Wallflower

Their attractions, however, are not limited to the beauties of form and colour and scent, though these are the features that bring them first to our notice. They are supremely interesting as well. Before, however, we set out to examine them, I must warn you that a little effort of memory will be needed. The separate parts of the flower all have their distinguishing names, and it is worth while to get these by heart, in order to follow clearly what I am going to say.

Suppose we select a Wallflower for examination. Each flower is poised on a slender stalk, which serves to hold it out to the sun and air and place it in a favourable position to receive the insects which play such an important part in its life-work. The flowers of some plants have no stalks, but grow straight from the stem. The lowest part of the Wallflower consists of a ring, or " whorl ", of four leaf-like members of a purplish colour tinged with green. Each individual " leaf " is called a *sepal*, and the entire ring is the *calyx*. In most plants the calyx is green. It serves, as a rule, to protect the inner organs of a flower, both in the bud-stage and later, and also to give the petals support. Within the calyx stand the four velvety *petals*, the entire whorl being known as the *corolla*. You may think of them as the shop-window of the flower, dressed as attractively as possible to attract customers, the customers in this case being mainly those that arrive by air. They also act as a protection to the delicate organs which I am about to mention.

Towards the centre of the bloom stands a ring of six delicate, thread-like stalks (two of which are shorter than the others), crowned with little, yellowish, oval boxes or lobes. These are the *stamens*. Their lobes are called *anthers*, and they are full of a magical yellow dust called *pollen*. What the magic consists of we shall hope to discover presently.



WALLFLOWER
A. Entire. B. Vertical section.

If you strip away the petals you will discover, in the very centre of the flower, a slender, green cylinder arising from the base of the bloom. At its summit is a little, two-lobed object joined by a short neck to the cylinder. The two-lobed object is called the *stigma*; the " neck " is the *style*; and the cylinder itself is the *ovary*. The ovary is hollow and, if you were to cut it open carefully and examine it through a good lens, you would see that it was divided into two chambers. You would furthermore discover that, small as they are, these chambers contained within their secret recesses a number of tiny infant bodies, called *ovules*. These minute specks of living matter are the beginnings of the seeds-to-be. The three combined features of ovary, style and stigma are spoken of as the *pistil*. The pistil is, in a sense, the most important part of the flower, because it is here that the seeds of new plants will be produced from the ovules.

It all sounds a little complicated, I agree; but, if you compare my description with the illustration, I think you will find your difficulties disappear. Perhaps it will help you if I set out the principal names again in another form:—

The *calyx* consists of the whorl of sepals.

The *corolla* consists of the whorl of petals.

Each *stamen* consists of a stalk with its anther. The anthers are full of pollen.

The *pistil* consists of the ovary, style and stigma.

The ovary contains the ovules, which later on will become seeds.

If that is not sufficient, here are the names again, this time in verse.

The *calyx* forms the outer whorl;
  Its sepals (mostly green)
The petals clasp; they shield the flower
  When in the bud unseen.

The petals in the next whorl
  The bright *corolla* form;
They're gaily dressed in every hue
  To make the insects swarm.

A *stamen* has an anther bright
  Set on a stalk below.
The anther's full of fairy dust
  That helps the seeds to grow.

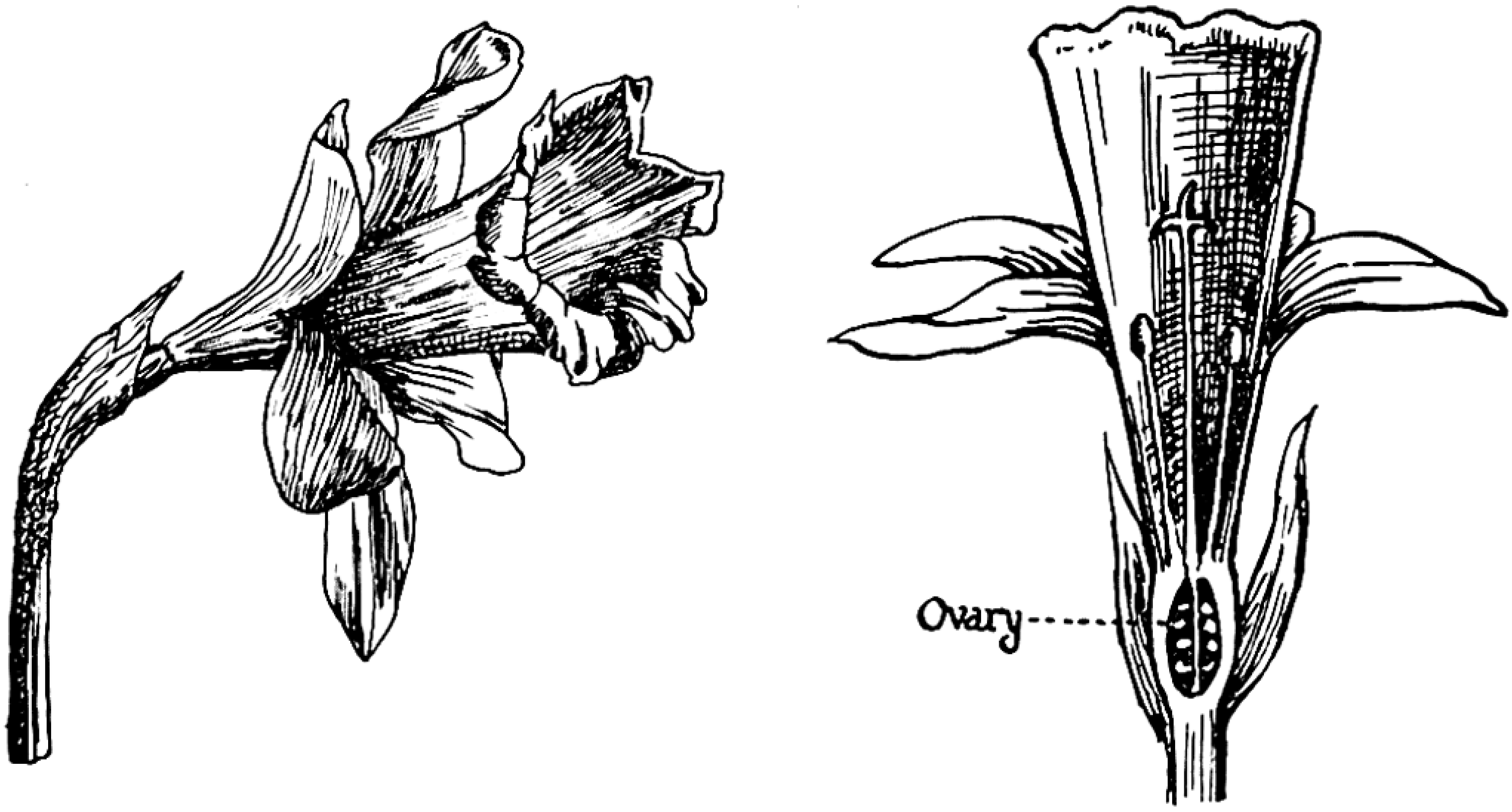
The *pistil*, mostly, has three parts—
  The stigma on the style
And, down below, the ovary,
  With ovules infantile.

Such is the arrangement of the parts of a comparatively simple flower. It is hardly necessary, however, for me to tell you that flowers vary very widely in their shape and structure. Compare the shape of the Wallflower with that of such blooms as Foxgloves, Sweet Peas, Dead-Nettles, Scarlet Pimpernels, Stitchworts, Hyacinths, Campions and Convolvuluses. Some of these are shaped like a trumpet, others like a bell. Some resemble an urn or a vase, while others are more or less "open" flowers, being shaped like a cup or a saucer. Finally, there are other shapes which we cannot liken to any object at all. As it is with the shape, so it is with the details of the various parts. Our Wallflower has four sepals, four petals and six stamens; but other blooms may have either more or less than this. So, too, the pistil may look quite different. The style, which, in the Wallflower, forms a short neck, may be a long, slender column. Often there are two or more styles; while sometimes there is no style at all and the stigma is seated directly on top of the ovary. The stigma, too, is often a round knob, sometimes nothing but a small swelling at the top of the style, while in some flowers it is split up into little branches. The ovary of the Wallflower is a slender cylinder with two chambers; but in other flowers it may have quite a different shape, often with only one chamber, but often, too, with several. In Buttercups, Lesser Celandines, Clematis, Strawberries, Roses and many other plants, each flower contains several *separate* ovaries.

There is, indeed, no end to the variations in the make-up of flowers. Some of these I will describe when we come to them; but it would be tedious to list them all, and it would be useless, too, for you could not possibly remember them. You must go to the flowers themselves and make your own discoveries; and you will find that, whatever the variations may be, there is usually no difficulty in distinguishing the different organs, except, of course, when they are too small to be discerned.

One feature, however, I will just mention before we go any further. It will help you to distinguish between the two great groups of flowering plants. In monocotyledons (Daffodils, Narcissi, Tulips, Bluebells, Snowdrops, Irises, Garlic, etc., etc.) the parts of the flower (sepals, petals, etc.) are commonly in threes or some multiple of three. The three sepals and the three petals, moreover, are usually coloured alike, and there is no clear difference between them. In dicotyledons the parts of the flower are very commonly in twos, fours or fives, or some multiple of them. Only a few have coloured sepals that might be confused with the petals.

Now that we have finished that little lesson, we can proceed with the more interesting study of how the separate parts of a flower share the great work of producing the seeds. The essential thing they have to do, if their labours are to succeed, is to contrive that some of the pollen from the anthers shall be brought into contact with the ovules. But, surely, you will say, that is impossible! The ovules are sealed up in the ovary like precious jewels securely locked in a casket, while the anthers stand apart with no apparent means of reaching them. How is it possible for the pollen to enter that secret chamber? Well, it certainly does seem rather a problem, but suppose we examine the anthers more closely, using a strong lens to aid our feeble sight and slicing them across to expose their interior. Thus seen, they become something more than brightly coloured lobes or simple boxes. Each one proves to consist of a pair of boxes; each box is divided into two compartments; and all four compartments are packed with the minute pollen-grains. So there is the first obstacle placed between the pollen and the ovules. It has to get out of the boxes.



Daffodil

What happens next? Wait till the pollen is ripe, and you will see the boxes split open as if at the touch of that magicians' wand that seems to be always performing some wonder in the quiet world of the plants. The pollen is now free to quit its narrow prison. The tiny grains spill out, aided by the least movement of the flower as it bends before the wind. It falls in a coloured cloud towards the heart of the flower, where the pistil waits with the ovules, or unformed seeds, buried in the darkness of its ovary. Some of it drops lightly on to the stigma. Once there, it will be securely held, for the surface of the stigma is usually sticky or hairy and will not allow it to escape. The first part of the journey is finished: the flower is *pollinated.* The pollen still has its obstacles to overcome before it can make contact with the ovules; but, before we follow it in that second part of its journey, there is a great deal more to be said about the first part.

The step I have just described is one in which a flower is *self-pollinated*—that is, pollen from its stamens is carried to its stigma. Experiments have proved, however, that in many plants a larger number of seeds are ripened, and often a stronger family of young plants reared from them, if the pollen is brought from another bloom of the same kind, especially if that bloom grows on a separate plant, and not on another stalk of the same plant. Plants seem to " know " this, just as they seem to " know " how the pollen can be brought to them from abroad, for they exhibit quite a number of devices to hinder self-pollination and to favour the other method of *cross-pollination.*

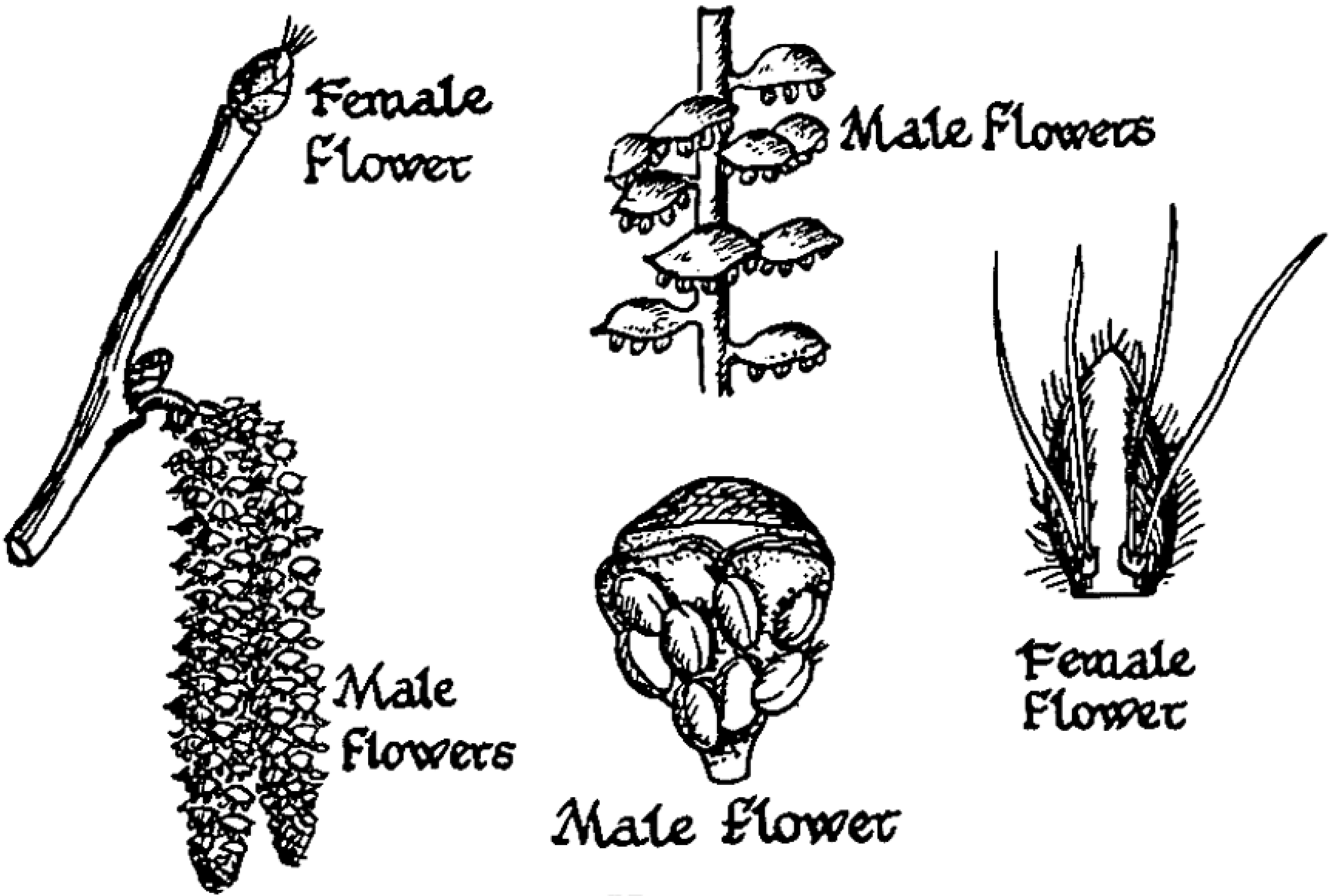
One of those devices will introduce us to two new forms of flower. In one form the flower possesses stamens, but it has no pistil. It is called a *staminate* flower. In the other form the flower possesses a pistil, but it has no stamens. It is a *pistillate* flower. You find both kinds of these flowers on the Oak, Birch, Hazel, Beech and certain other trees, and also on the Stinging-Nettle and the Dog's Mercury. Obviously such flowers cannot possibly pollinate themselves. The staminate flowers, of course, having no pistil (and therefore no ovules), cannot produce seed at all. Their duty is merely to provide pollen for the pistillate flowers, which *can* produce seed. The Dog's Mercury, in common with a number of other plants, cannot even be pollinated from other flowers growing on the same *plant*; for it bears none but staminate flowers on one plant and none but pistillate flowers on another.

In very many flowers (Canterbury Bells and Plantains for instance), although both stamens and pistil are present, the pollen does not ordinarily ripen at the time when the stigma is in a condition to receive it, so that each flower must wait for pollen to be brought to it from another flower. It seems rather rash of a plant to gamble on the chance of this happening, yet it has not necessarily staked everything on the event. If fortune proves to be against it, it often succeeds in pollinating itself—which is a good deal better than not being pollinated at all—just before it begins to wither.

In the Meadow Buttercup and some other blooms the pollen may reach the stigma of its own flower, but it is ineffective. That is to say, the flower is *self-sterile*, and so, as in the other cases, it must rely on cross-pollination. Other devices which flowers exhibit are the arrangement of their stamens and stigmas in such a way that the pollen is unlikely to fall on their own stigmas. For instance, the stigmas project beyond the anthers, so that the pollen would often have to rise (instead of falling, as it naturally would) in order to reach them.

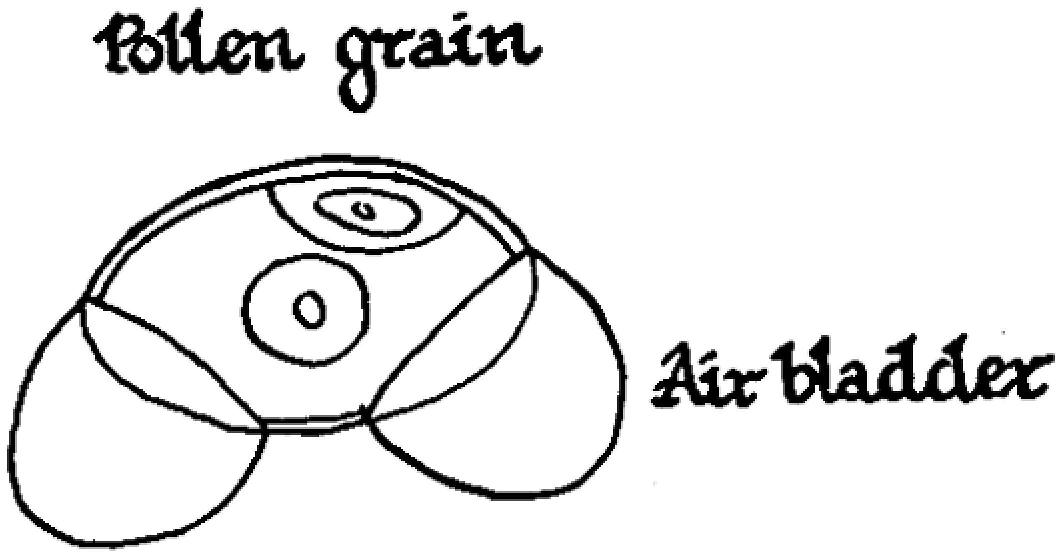
These are some of the means by which flowers hinder self-pollination and thus hold themselves ready for cross-pollination. When we come to consider how cross-pollination actually takes place, we realise that the flowers which rely on it have something of a task to perform. They themselves stand fixed on the stems, and the stems in turn are set immovably in the soil; yet they expect to command a supply of pollen from other blooms on the stems, or perhaps from other plants growing an unknown distance away. Let us see if we can discover how their expectations come to be realised. The actual transport of the precious cargo is, in nearly all cases, made either by the wind or by insects—flies, beetles, moths, butterflies, wasps and bees. These are the diverse agents which are enlisted in the plants' service, and I will show you presently how you can tell which of the two kinds of servant—wind or insects—is employed.

Go out and stand beneath a Hazel bush on a windy day when the pollen of the staminate flowers is ripe. The long, loose catkins—which are simply crowded masses of tiny, separate, staminate flowers—are shaken to and fro by the breeze, wriggling like the tails of so many lambs at play. The motion is sufficient to bring out the light dry pollen in a golden cloud. Much of it is lost as the wind bears it away, but some of it will settle on the crimson stigmas of the pistillate flowers set apart on the branches below. Thus the flowers are pollinated, like the one we looked



HAZEL
Male is Staminate. Female is Pistillate.

at a while ago, only these have received the pollen from other blooms. They are *cross*-pollinated. You see the same thing happen to Oaks and Birches and Alders and several other trees, as well as to many lesser plants, such as Dog's Mercury, Stinging-Nettle and Plantains. In the latter plant each flower contains both stamens and pistil, but in this and similar cases self-pollination is guarded against to a great extent because the anthers and the stigma of the same flower do not mature together.



POLLEN GRAIN OF SCOTS PINE

Flowers that rely on the wind for pollination usually produce much more pollen than those which favour insects, for the wind is an erratic and unruly porter, and loses far more of the fertilising dust than it delivers. The pollen, too, is made especially light and dry, so that it may travel far—often an essential condition where the staminate flowers grow on another plant. The Scots Pine fits each separate grain with a pair of air-bladders to increase its buoyancy, like those that support you in the sea when you are learning to swim. It is, too, so lavish in its production that you may sometimes find the yellow powder lying on the ground in small drifts. I have even heard of timid country people who wondered if these accumulations were brimstone deposited during a terrific thunderstorm or even some distant earthquake. The great naturalist Darwin discovered some astonishing facts about the quantities, and the range, of pollen produced by plants whose flowers are pollinated by the wind. Bucketsful, he said, had been swept off the decks of vessels near the North American coast, and in Missouri the ground had been seen covered with grains that might have travelled from Pine forests four hundred miles away. In modern times experiments have been made which prove that pollen is often carried at great heights by the wind, for aeroplanes have succeeded in catching the grains on sticky plates.

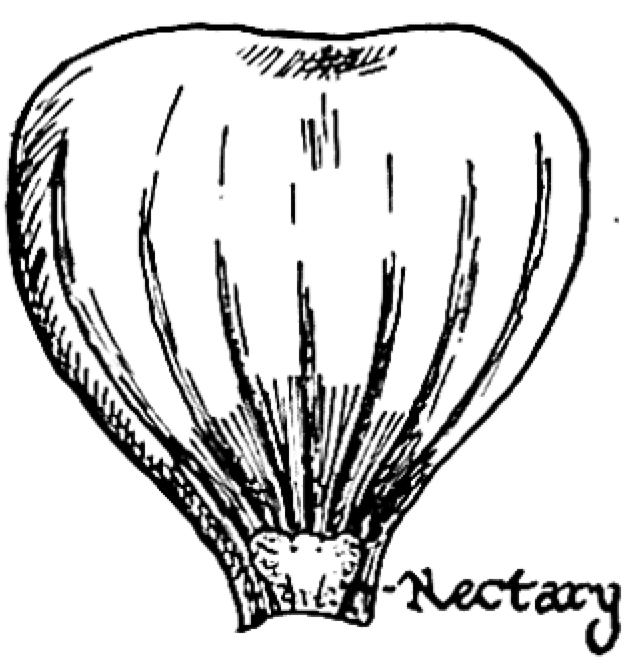
Other features that distinguish wind-pollinated flowers are the attachment of their anthers to long, slender stalks that sway with the lightest breath of wind, and the development of branched and feathery stigmas that present a larger and more receptive surface to the flying grains. The Ribwort Plantain is a beautiful instance of the former feature. Each spike contains a mass of separate flowers with long stamen-stalks that stand well out all around and bear yellow anthers that flutter like so many tiny flags hung out on a gala day. On the other hand, as such plants do not look to the bees and other insects to help them, there is no need to lay themselves out to attract these creatures. Consequently you find that the individual flowers are usually small and unattractive (though they may be showy enough when massed in catkins and spikes), and that they yield neither scent nor "honey". You have only to consider the flowers I have mentioned above to realise that this is so.

Well, so much for wind-pollinated flowers. Now let us turn to the great multitude of plants that depend on insects for cross-pollination. Here we find flowers with the most astonishing adaptations and variations, all evolved with the one supreme object of enticing the winged world to come and visit them. Indeed, it is in studying this, the highest stage of a plant's activities, that we are most tempted to believe that flowers are endowed with intelligence like ourselves. Scientists, however, account in other ways for what, at first sight, might be taken for conscious planning. Their explanations are too deep for our understanding at present, so we will content ourselves with studying the marvellous results achieved and pondering over them as we feel inclined.

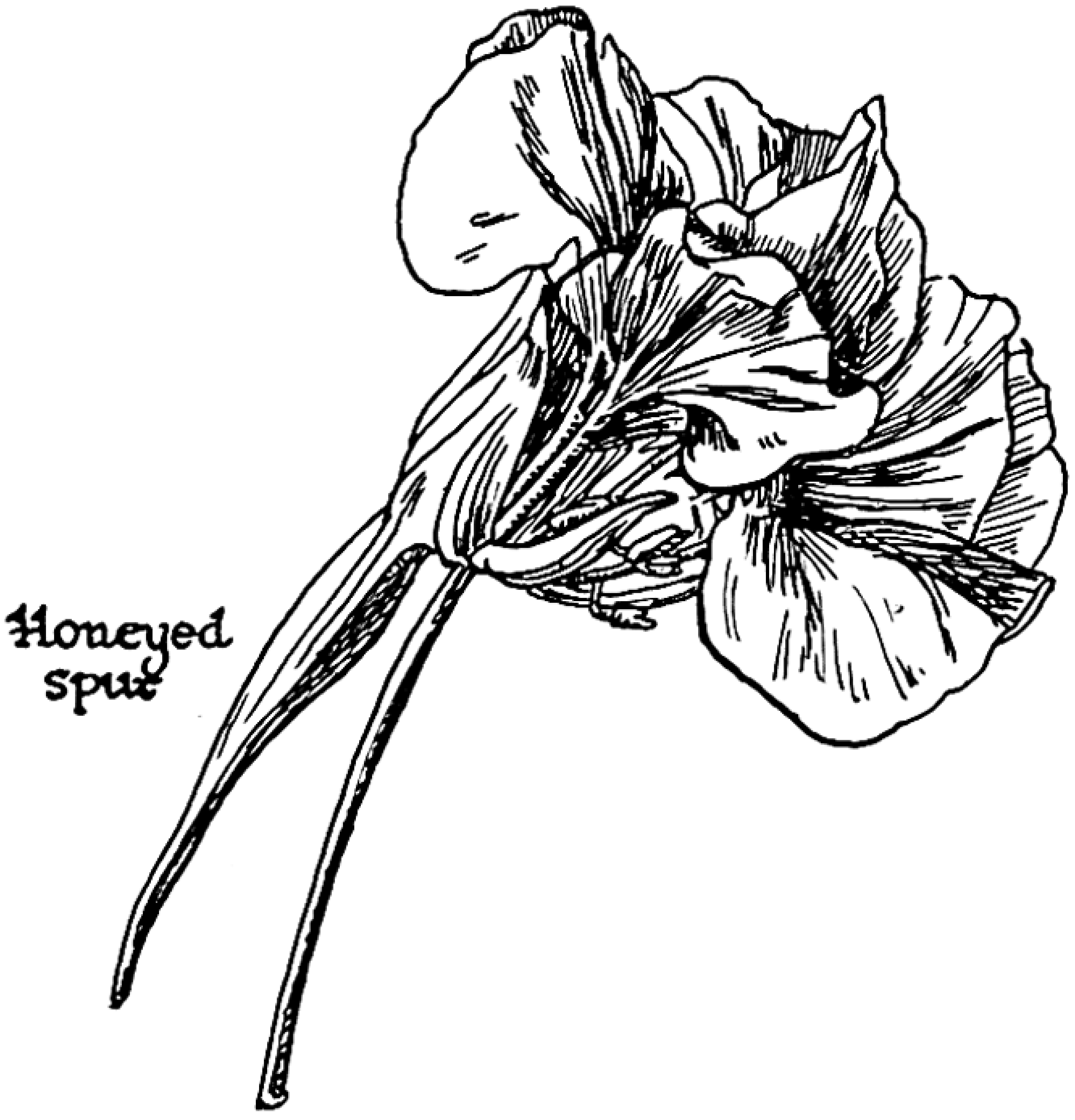
It is as though the flowers sent out a radio invitation to the insect world, accompanying their message with enticing promises of a delicious feast and planning their houses so that the visitors should enjoy the spread with the least possible effort on their parts.

Of all the insects that undertake the pleasant and profitable office of pollen-carriers, the bees are the most familiar to us. We see them soar aloft, booming past our faces, too busy to notice our groundless fear of being stung. They are intent on work and pleasure combined. Let us watch one of the busy sisters. She cleaves the air in a wide-sweeping flight, bent on some distant object that attracts her senses. It is the brilliant colour of a flower—perhaps a blue or purple flower, for bees seem to love those colours. Perhaps there is scent as well. Colour and scent are the plant's form of invitation. They are like tiny voices raised in eager appeal to the distant insect, calling insistently, *Come! come!* And the bee responds with the utmost readiness. This, she thinks, promises something good. She must speed away and investigate. She does; she reaches the scented blossom, lights on the expanded petals and forthwith becomes intoxicated with the heavy scent of "honey" and the vision of a banquet of golden pollen. It is not really honey yet. Its proper name is nectar, but it matures into honey after the bee has worked it up, taken it to the hive and stored it away in the comb. It is the principal food on which the colony lives, and the bees collect it all from the plants. The pollen constitutes their other food, serving them for bread. It is, in fact, often called "bee-bread", and it is as indispensable to them as bread is to us.

Well, bread is all very well in its way, but sweeter foods are more desirable and equally essential. Bees and other insects are more surely attracted by nectar than by pollen. I daresay you know as well as I that nectar is deliciously sugary, because you must have sucked it from Clover blooms and Pansies yourself. The flowers secrete it in little glands called *nectaries*, situated usually near the base of the bloom. Sometimes they are placed around the ovary, sometimes at the foot of the stamen-stalks. In Buttercups they are protected by a flap which forms a tiny pocket at the base of the petal, as you can discover for yourself. In Pansies and Nasturtiums the nectar accumulates in the long tubes or spurs which grow out behind the flower.

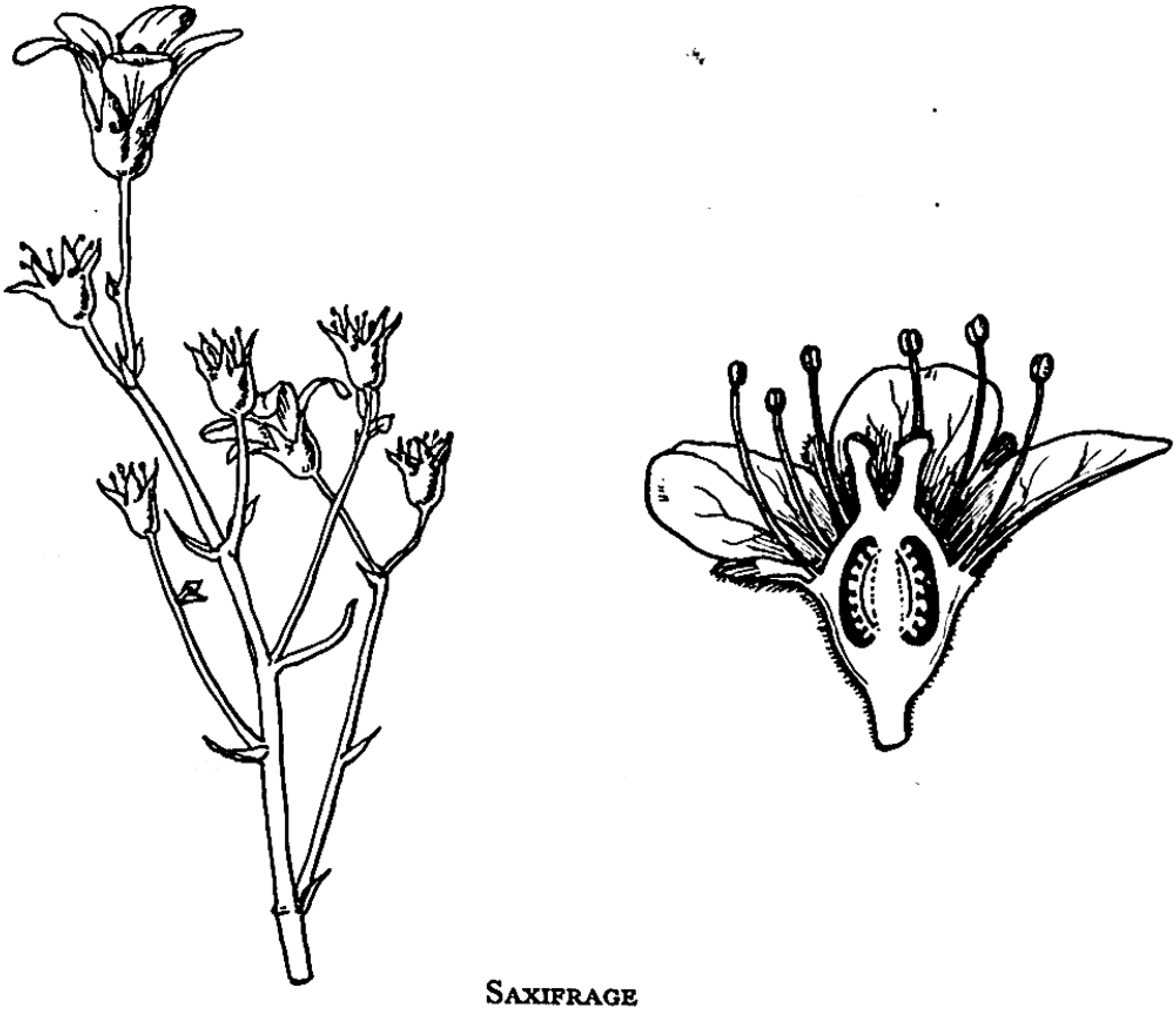


Petal of Buttercup, showing Nectary



Nasturtium, showing Honeyed Spur

Whatever position is adopted for the nectaries, there is good reason for the choice. Many flowers, you see, are distinctly snobbish or selective in their behaviour. They do not issue an invitation to all and sundry insects, but limit it to particular classes. Some, for instance, have a special liking for bees; others prefer the night-flying moths; and, in laying out the feast, only those favoured guests are given access to the table. The position of the nectaries forms one of the most effective means by which a flower (when it shows any preference at all) selects its visitors. You would think it knew all about insects and their shapes—how some have big bodies and some small, how all of them have "tongues" with which they suck or lap up the nectar, and that those tongues vary greatly in length. At any rate the nectar is placed at such a depth that only the particular creatures it favours can reach it, while its other organs are so arranged that the visitors will duly effect pollination as they feed. Thus, when the nectar is contained in open or shallow flowers, as in Saxifrages and Stonecrops, the short-tongued flies and beetles, and of course the whole army of long-tongued insects as well, can revel in it to their hearts' content. But when, as in blooms like the Willow-herb and the Mint, the repast is spread at the bottom of a short tube too narrow for the insect to enter, or whose entrance is defended



Saxifrage

by a jungle of hairs or other obstacles, the small riff-raff of the winged crew may stretch their tiny tongues to their fullest extent, but they cannot reach the tempting sweets. With this type of flower, hive-bees and certain of the wild bees, wasps and the longest-tongued flies, as well as insects with still longer tongues, are the favoured creatures.

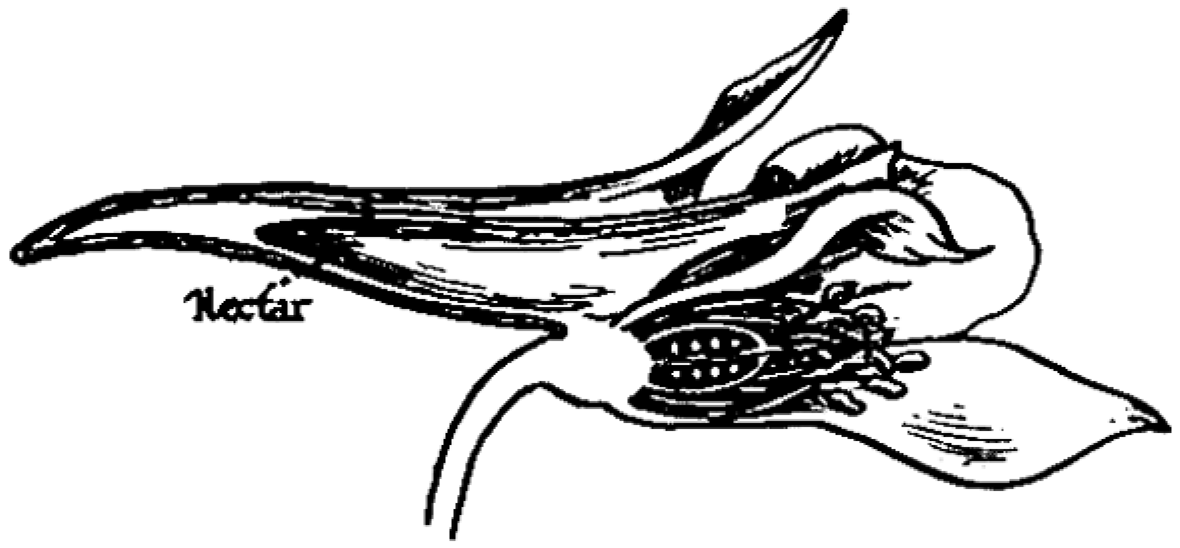
This selective method is carried further and further in different types of flower by lengthening the narrow tube down which the hungry insect must pass its exploring tongue, or by other equally effective means. Thus, most of the flowers of the (monocotyledonous) Daffodil, Lily and Iris families are a preserve of the humble-bee and other large bees, and of butterflies and moths, all of which are blessed with a generous length of tongue; while the fragrant Honeysuckle secretes its nectar in such an extended tube that only certain moths with an exceptionally long tongue can reach it.

The device, however, is sometimes seen to fail, and gate-crashers force their way in to the forbidden sweets. The humble-bee—a very intelligent creature—will often bite its way through the bottom of a tube from the outside and help itself to the nectar without rendering any service to the plant in return. In the Larkspur this back-door method of entry is checked by the construction of a honeyed spur with a double wall. The burglar, having bitten through one defence, finds itself confronted with another; and as, for all it knows, there may be still further walls within, it relinquishes its onslaught in disgust. Of course an insect excluded from the nectar of a flower may partly console itself with a plain meal of pollen as the next best thing; but it is a poor satisfaction to be offered dry bread when you know there is cake in the cupboard.

There are various other ways, particularly in connection with the shape and grouping of the different organs, in which particular flowers adapt themselves to receive particular insects for the purpose of pollination. These are extremely fascinating to study, though they are far too numerous and complicated for me to describe in full. I feel, however, that I must touch on a few of them so as to set you examining them in the fields for yourselves, and I will take the opportunity of doing this, and of drawing your attention to certain other striking adaptations, as we follow the flight of the bee that we have almost forgotten while we dallied behind talking of nectar.

Let us suppose that the bee makes for a field of Clover, whose scented blooms are rich in nectar. These flowers are very different in form from the simple Wallflower type. They belong to a group, all of similar construction, which includes Gorse, Broom, Rest-harrow, Bird's-foot- and other Trefoils, Peas, Beans and many other plants. In such flowers the two lowest petals are joined together underneath (and sometimes to some extent above), and look rather like a little boat. They are called the *keel*, and in them lie the stamens and the pistil. Two more petals form a pair of *wings* spread out on either side, and a large fifth petal, the *standard*, stands boldly up like a flag behind them. The flowers are mostly visited by bees, because smaller insects are not heavy enough to set the mechanism working.

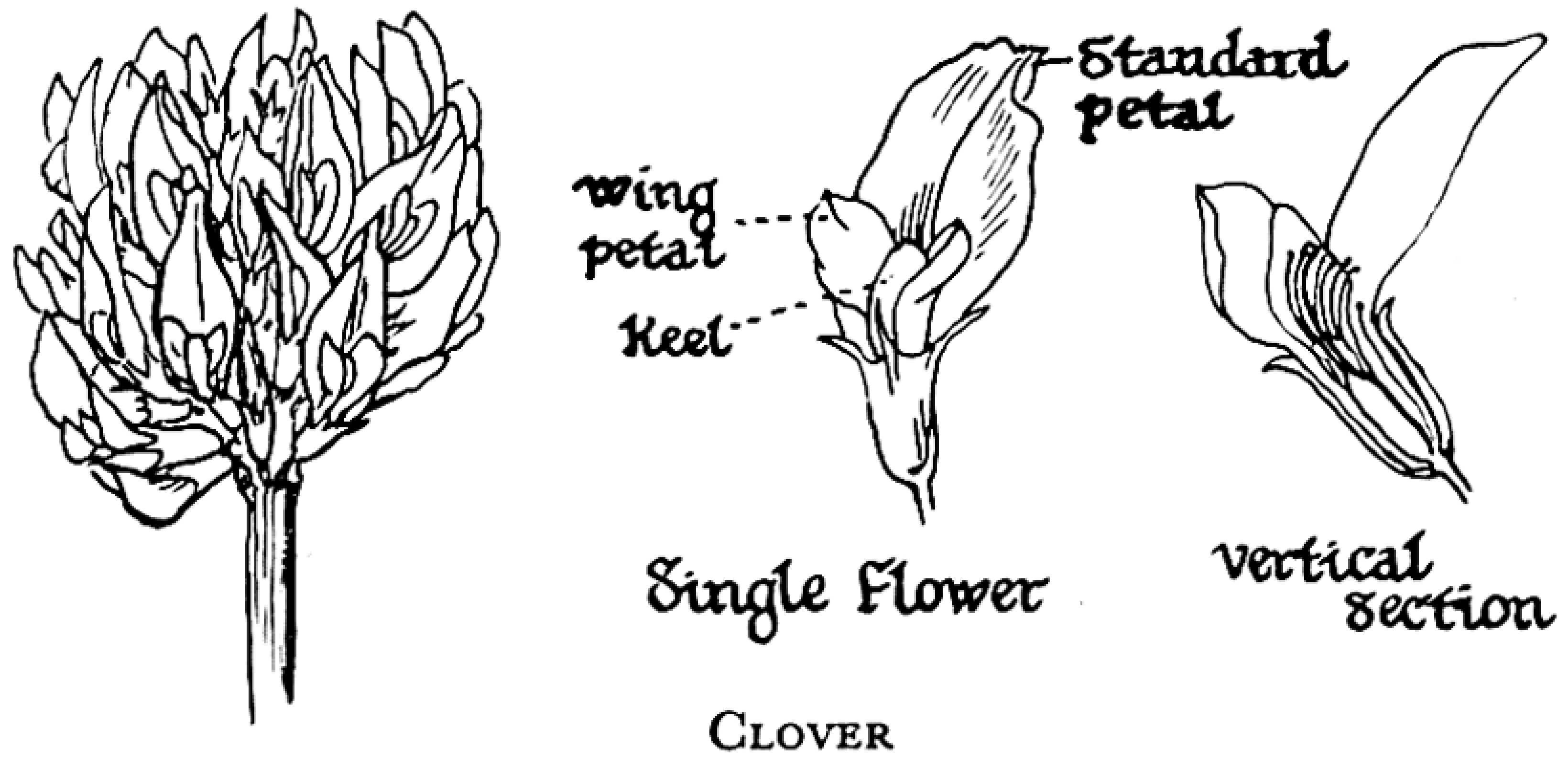
Tongue of Bee



Larkspur

Our hungry bee alights on one of the florets in the Clover-head, pressing down the keel and wings by her weight as she fusses importantly amongst the odorous petals. The immediate result is that the cluster of stamens and the long style with its stigma emerge from the keel. They brush against the underside of the bee as its tongue goes searching for the nectar. This lies in a trough constructed by uniting the bases of most of the stamen-stalks in a tube around the ovary. Some of the pollen clusters on the bee's hairy coat. Now she has extracted all that the bloom has to offer, the nectar is passed into her honey-bag, and she turns her attention to the next floret. Once again we see her alight. Wings and keel go down. Out come the stamens and the style and stigma. They sweep against her body, *where the pollen from the first flower is clinging*, and some of the golden dust is transferred to the stigma. The flower is cross-pollinated. It is true that, in this and other flowers I shall mention, some of the pollen-grains may reach the stigma of their own flower; but self-pollination is avoided, at least in many instances, by the devices I have told you of before—*e.g.*, by the flower being self-sterile, or by the anthers and stigma maturing at different times. It is a curious fact, though, that Garden Peas are regularly self-pollinated, none of our bees being heavy enough to force open the flowers.

The Sweet Pea displays a neat little trick to secure cross-pollination. The little boat formed by the keel is more or less closed in at the top as well as at the bottom, and it has a beaked prow, like that of an ancient Viking ship, with a hole at the tip.



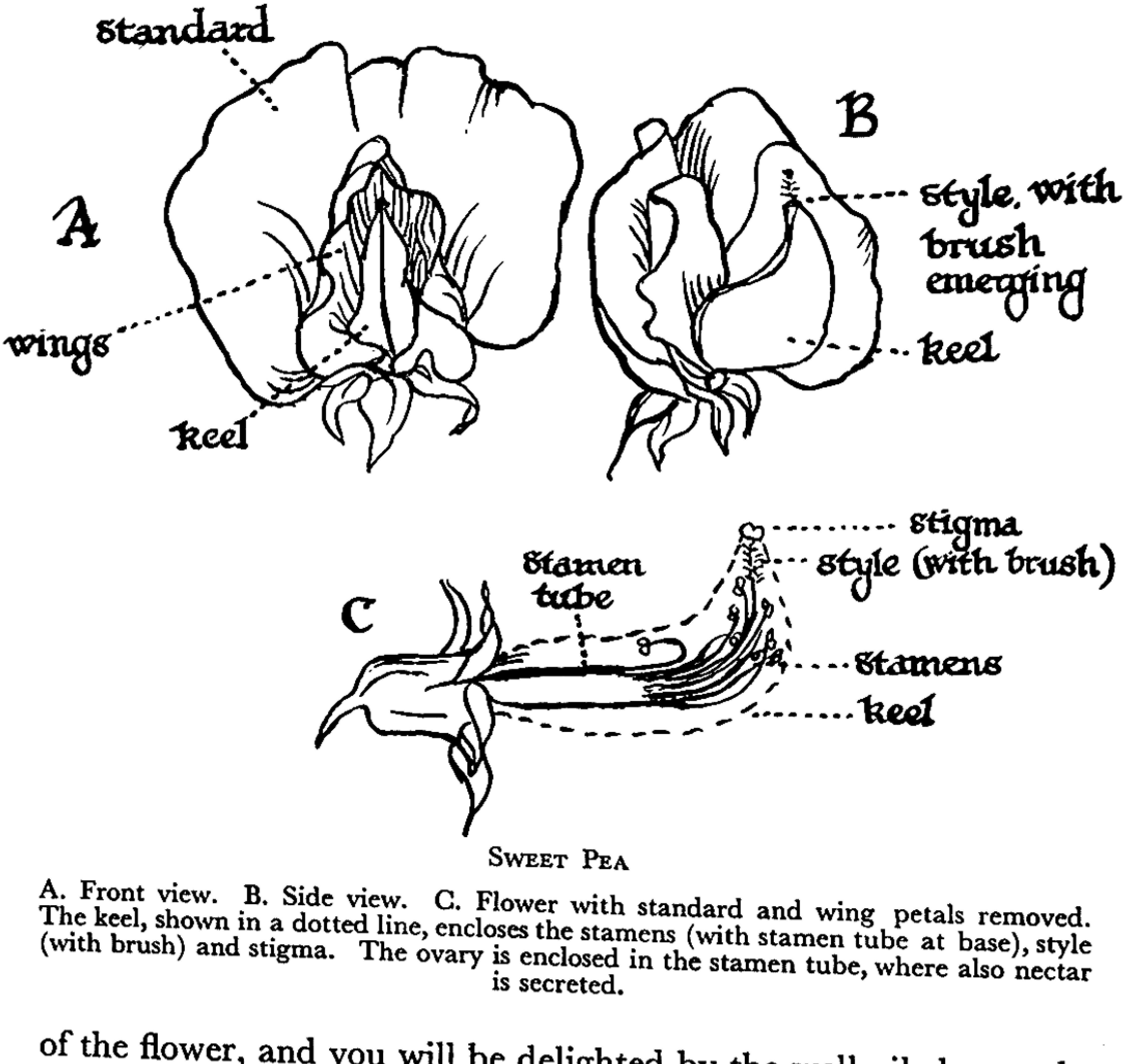
Single Flower

vertical section

CLOVER

The vertical section shows stigma, stamens and trough containing ovary.

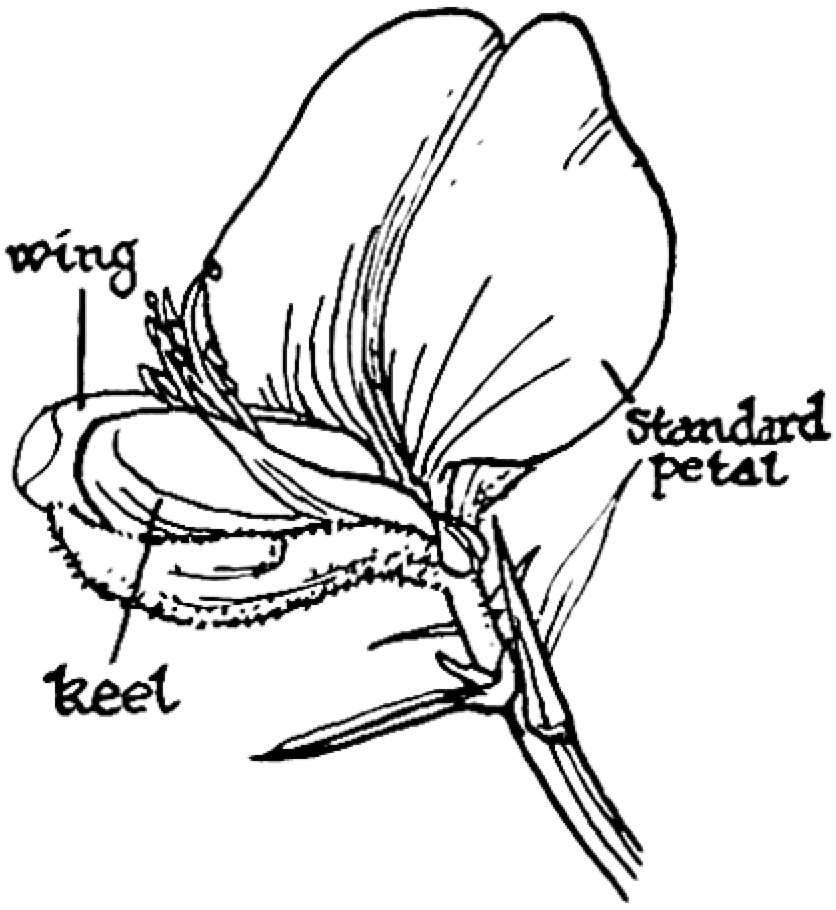
The orange-coloured anthers lie in the prow, surrounding the stiff upward-curving style. The style is fitted with a brush of hairs, and on to this some pollen falls from the anthers. When a bee alights and presses down the keel, the style and stigma are forced out through the beak. The stigma rubs vigorously against the underside of the bee's body, and the brush, sweeping out the fallen pollen, liberally sprinkles the insect as it regales itself, the stamens remaining in the keel. Later, when she visits another Pea-flower, the performance will be repeated; but some of the pollen adhering to her body from the first flower will detach itself on to the stigma of the later flower, and so cross-pollinate the bloom. Several other flowers, including those of the Broad Bean and most of the Vetches, have a similar brush or tuft of hairs serving the same purpose. In the Bird's-foot Trefoil and other blooms some of the stamens are swollen just below their anthers, and act as a piston for forcing out the pollen through the tip of the beak when the keel is depressed. You can set the piston in operation, and make the pollen emerge, by pressing on the keel of the flower, and you will be delighted by the well-oiled smoothness of its action.



Sweet Pea

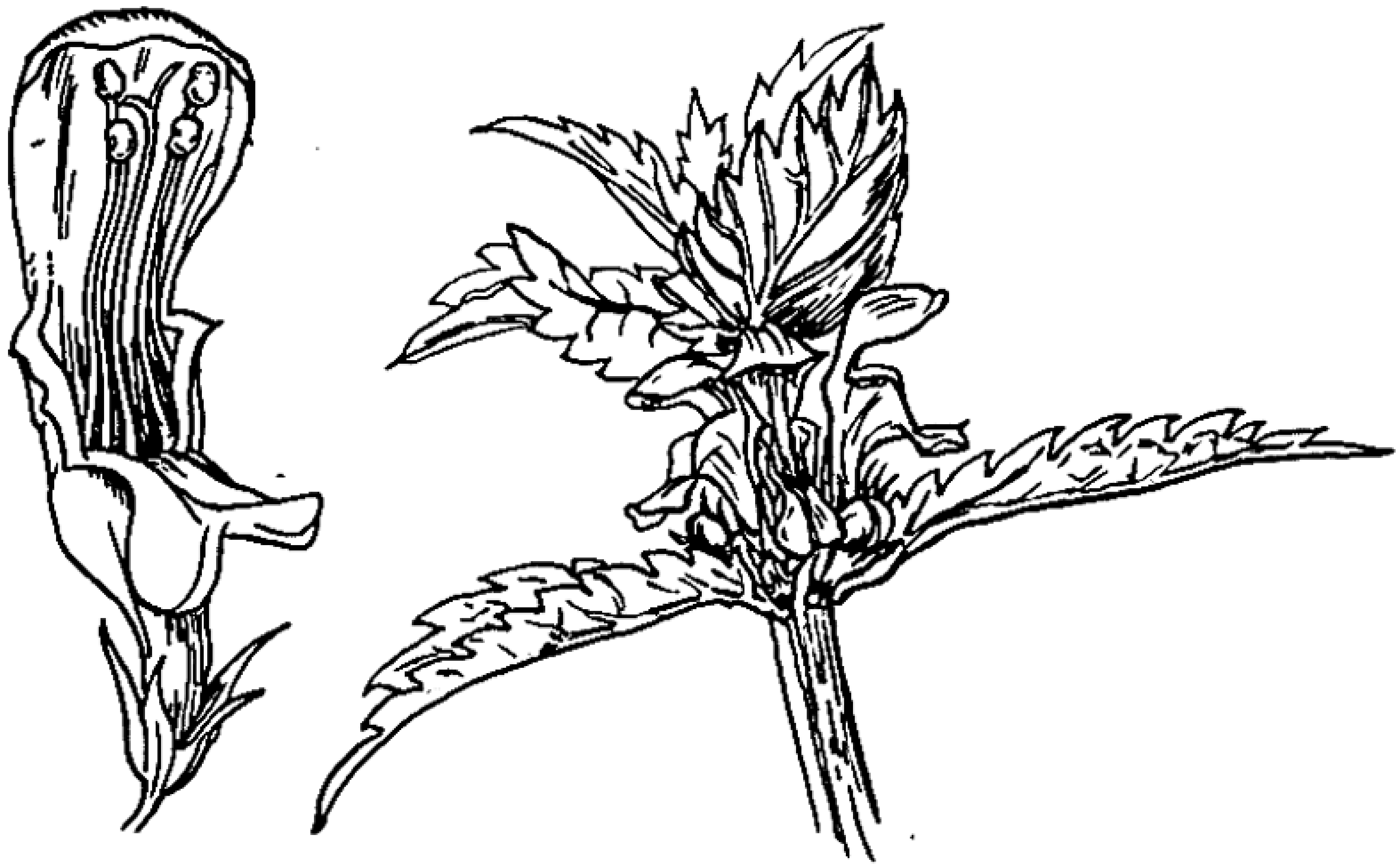
A. Front view. B. Side view. C. Flower with standard and wing petals removed. The keel, shown in a dotted line, encloses the stamens (with stamen tube at base), style (with brush) and stigma. The ovary is enclosed in the stamen tube, where also nectar is secreted.

The Gorse and the Broom receive their callers in a rather startling manner. Their flowers do not produce nectar, so the bee visits them solely for pollen—or at least that is all she finds there, whatever her hopes may be. No sooner does she alight than the style, with the stigma and stamens, which have been confined in the keel rather tightly, like a spring, burst from their quarters, spraying the astonished creature's stomach with the golden pollen in a miniature bombardment. Uncle Fred showed us how we could fire off the mechanism for ourselves. He inserted the point of a pencil at the base of the standard, pressing down the wings and keel in imitation of the bee's action. Out flew the style, stigma and stamens and, with them, a tiny shower of yellow pollen. If we previously wetted the pencil, the fine dust stuck to it just as it would to the coat of the bee, all ready to be transferred to the stigma of the next flower it rifled.

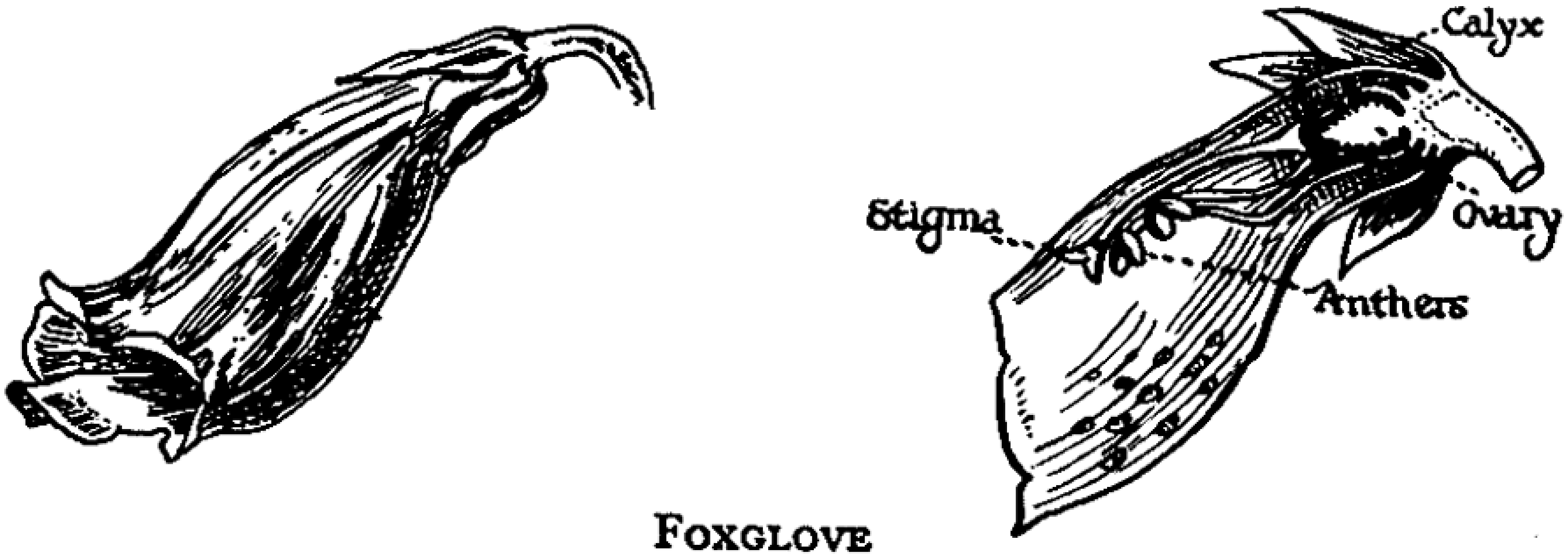


Gorse Flower with one Wing Petal removed to show Pistil

Now let us suppose that our foraging bee is visiting flowers of the Dead Nettle type. This is another distinctive form, and you can study it in Wood Sage, Self-heal, Woundwort, Ground Ivy and numerous other plants. It is a curiously shaped flower, but none the less successfully adapted for its ends. It has a tube which widens out into two big, irregular parts. One part is specially shaped to form a convenient landing-stage for its aerial visitors. The other serves as an overhanging hood to shelter from rain and dew the long-stalked stamens and the forked stigma that springs from the ovary below. (The Wood Sage has practically no hood, which makes the landing-stage all the more conspicuous; so much so, in fact, that the flower always reminds me of a panting puppy with its tongue lolling out.) At either side of the landing-stage in this type of flower there is a small additional ledge to accommodate the insect's fore-feet, thus making complete provision for its comfort at table. In some of the flowers a palisade of hairs is erected around the entrance to the tube to guard the nectar secreted within from small insects that would otherwise creep in and pilfer it without touching the anthers. Our bee, however, is more than welcome, and it is a delightful pastime to lie in the warm grass and watch her journeying from bloom to bloom. She grips the petals brusquely with her feet and takes possession of the flower in the most autocratic manner. She has no consideration for the delicate fabric of the prize she has seized, but roughly forces her great hairy body into the corolla and rifles the honey tube of its hidden sweets. She little knows that in every swaggering step she takes she is but following a path laid down for her in the construction of the flower. Her body, you see, is of a size to fill the gaping corolla, and so, as she hurtles about, her back rubs against the stigma and anthers bending over her from beneath the hood. Pollen is detached on to her back, and when she takes herself off and goes booming into the next flower, some of it will be brushed off on to its waiting stigma.



DEAD NETTLE, SHOWING LEDGES AS WELL AS LANDING STAGE

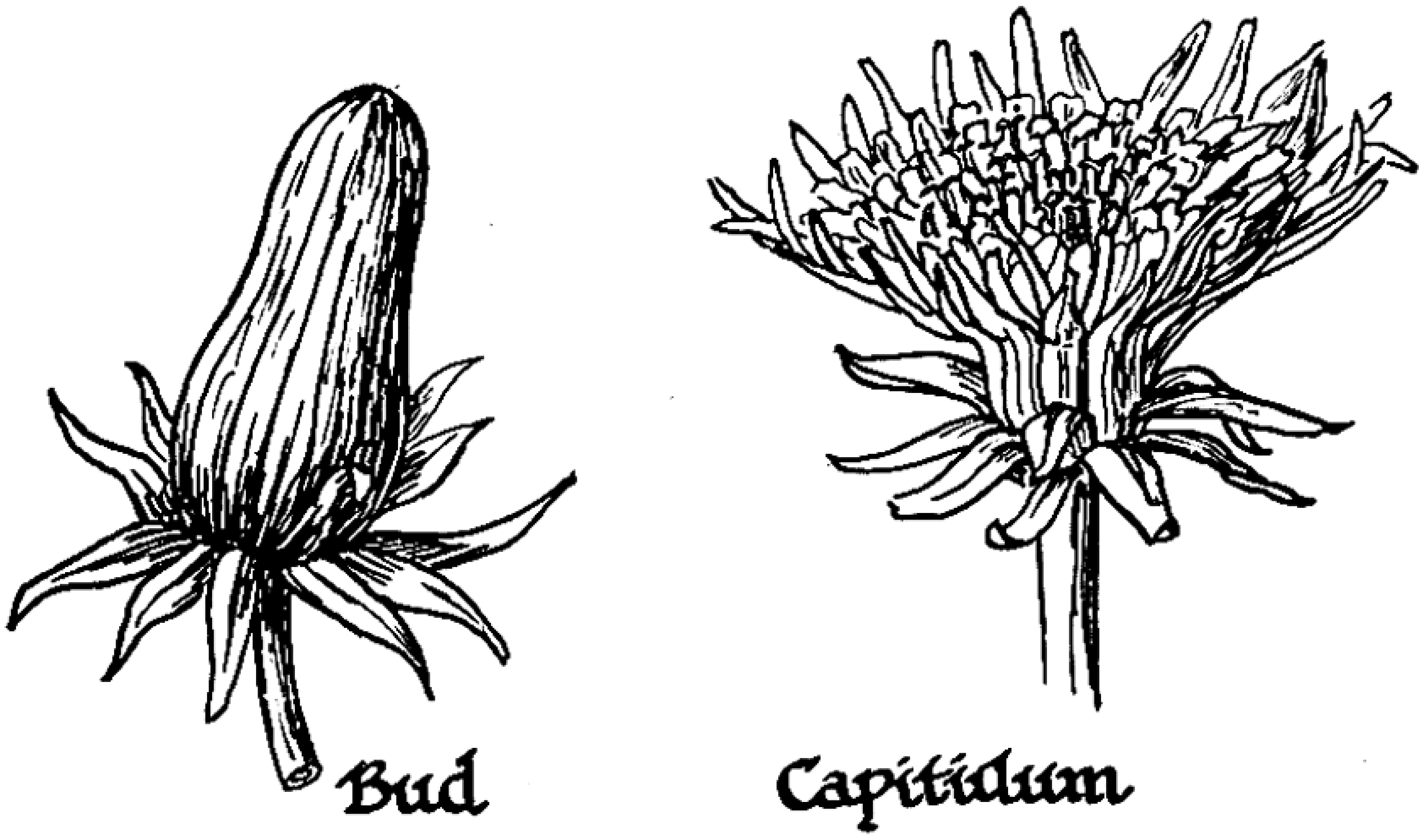


FOXGLOVE

Foxgloves secure cross-pollination by a similar arrangement of their stamens and stigmas, although, of course, the petals are quite differently shaped. The livid purple spots, surrounded by rings of white, which decorate the inside of the corolla, are said to serve as finger-posts to the bees, directing them to the nectaries. The lines and other bold markings of flowers in general are supposed to have the same meaning, but I feel fairly certain that bees are quite intelligent enough to discover the flowers' domestic larders without such aids. The Snapdragon and the Toadflax have a device designed to shut out all but comparatively heavy insects, such as humble-bees. They close up the entrance to their flowers with a large, bulging pouch produced from the lower lip and pressing tightly against the hinder petal, as if it worked on a spring hinge. Flies and other undesirables are largely excluded because they have not the strength to force the doors thus firmly closed. A number of the smaller kind do, nevertheless, squeeze through to get at the nectar, but it is quite another matter for them to get out again. As an eminent naturalist (speaking of the Snapdragon) once wrote, the flower is a strong-box of which the humble-bee only has the key.

In common with most people, I used to despise the Dandelion as a troublesome and unattractive weed. Uncle Fred, however, soon put me right on that by demonstrating its beautiful pollinating mechanism. And here I must stop and put *you* right on a common feature which this plant illustrates. We are apt to speak of such a bloom as the Daisy or the Dandelion as a single flower; yet the truth is that every such bloom is a head containing scores, or even hundreds, of separate flowers, or "florets". Each "petal", whether it be one of the flat, or strap-shaped, ones in either flower, or one of the tube-shaped ones in the centre of the Daisy, is (with the minute organs attached to it) a distinct flower.

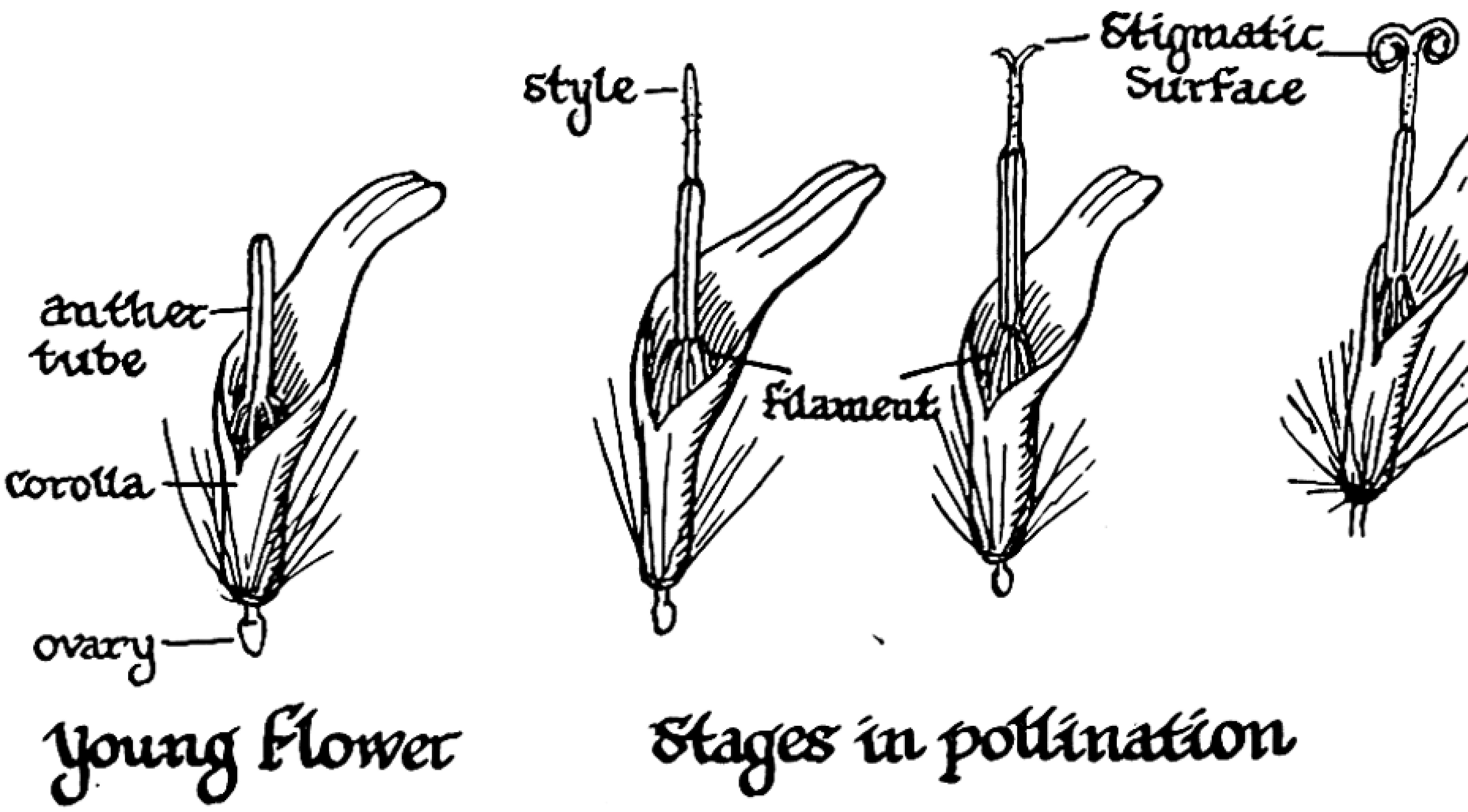
Each floret of the Dandelion head has a strap-shaped petal widening out from a tube right down in the tiny heart of the bloom; and, though the organs are not altogether easy to distinguish, there are five stamens and a pistil as well. The stamens are rather unusual, for their lengthened *anthers* unite to form a tube. The short style springs from the ovary lying at the very base of the floret, and its stigma reaches the lower end of the anther-tube. The stigma is divided into two upright lobes. When the anthers are ripe, they shed their pollen into the tube so that it falls on top of the stigma; but the flower cannot be self-fertilised because, at this stage, the two lobes of the stigma are kept pressed tightly together. Only their inner faces are receptive to pollen, and these the pollen cannot reach. Presently the style begins to push its way up the tube and, by means of a number of hairs set on its upper part, it sweeps out the pollen without getting any on to its closed up stigma. If our bee visits the flower-head now, it may find a numerous company of insects—other bees and flies and beetles and butterflies as well—assembled to taste the honey and pollen which is freely offered to all. These creatures will transfer some of the pollen to other florets in the head (probably also to florets in other heads) in which the stigmas have grown a stage further and become ready to receive it. Thus cross-pollination will take place.


Bud
Capitulum

DANDELION
Opening of bud into a head of florets called a capitulum.

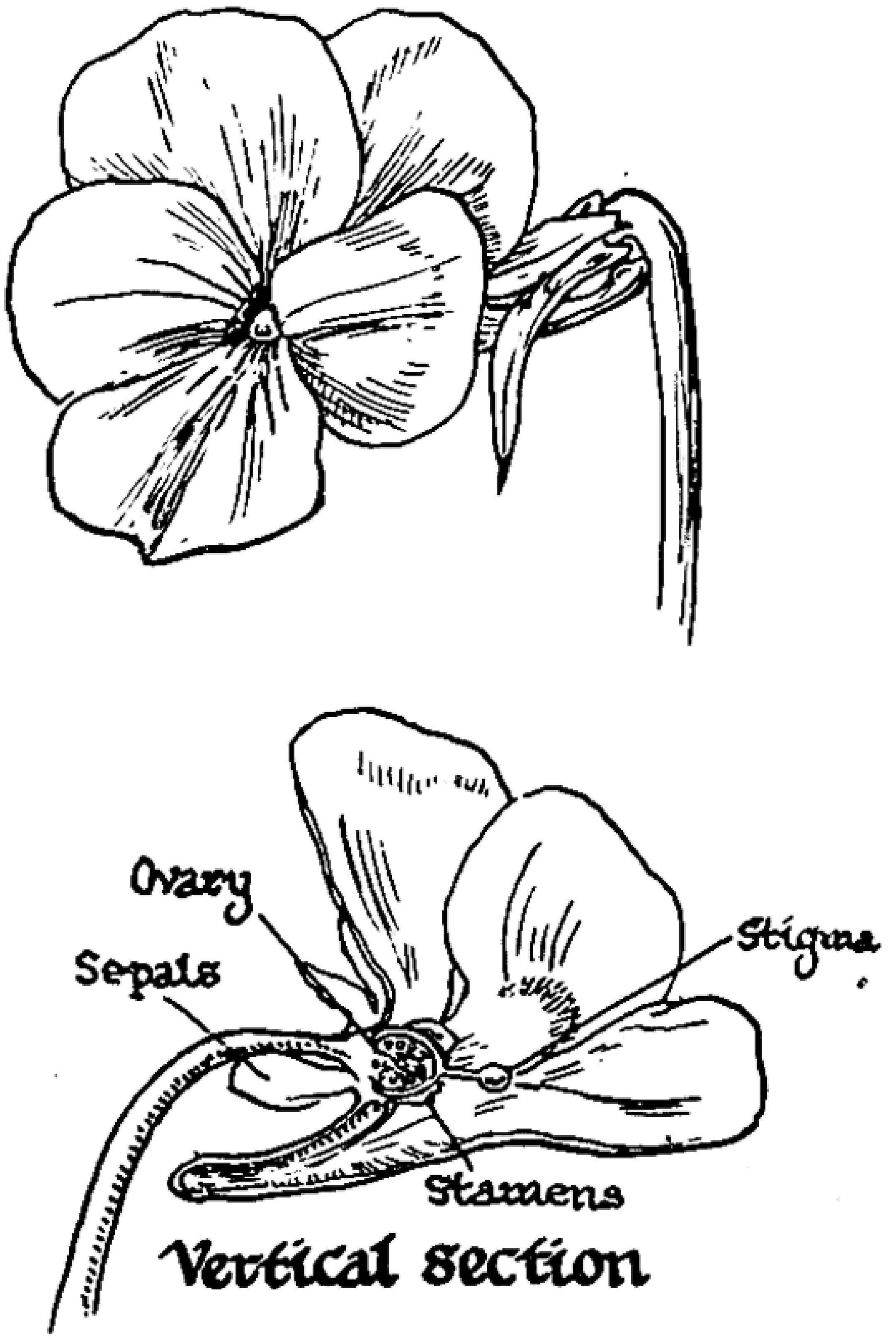
Now let us look at a number of florets in different stages of growth and see *how* the stigmas become ready to receive pollen from other florets. The style, we discover, continues to grow up through the tube, brushing out the pollen as it goes, until in time it emerges at the top. Here, being free of all danger of coming into contact with its own pollen below, the lobes of the stigma curl apart and expose their inner surfaces. It is at this stage that they are ready to receive pollen from another floret. But this is not all. If the floret fails to secure cross-pollination it is capable of pollinating itself as a last resort. At a still later stage the lobes of the stigma curl right back like a ram's horns until they come in contact with some of the pollen still remaining attached to the hairs on the style. Thus the floret becomes self-pollinated, if it has not previously been cross-pollinated.

This ingenious method is not the exclusive patent of the Dandelion, but is shared by Hawkweeds, Thistles, Daisies, Ragworts, Knapweeds and scores of other plants which bear their blooms in heads of massed florets. In some of these (the Daisy, for instance) only the central florets, which have a tube-shaped petal, are complete with stamens and pistil, the outer or ray-florets, with strap-shaped petals, having no stamens. There are other variations, but we need not trouble about them now.

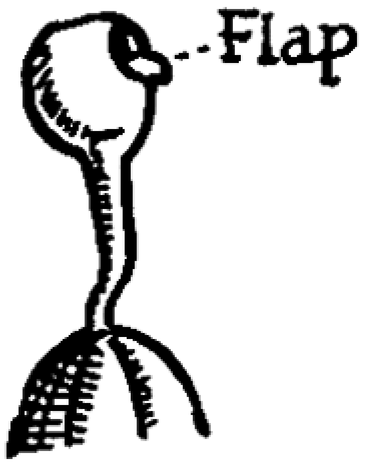


DANDELION
This shows also growth of calyx of hairs to form parachute of fruit.
Filaments are stamen-stalks.

The flower whose method of pollination fascinated us most when my uncle explained it was the Pansy. The flower is, of course, quite familiar to you, so I need not describe it. When our bee comes droning through the air like a rather unsteady aeroplane and settles on the alighting ground provided by the long lower petal, she thrusts her tongue deep down into the spur behind and greedily draws up the nectar secreted there. In doing so some pollen from the anthers, which are situated in a close ring just beneath the stigma, is brushed off on to her tongue. You might expect that, in withdrawing that lengthy organ, some of the grains would cling to the stigma and so bring about self-pollination. But no: the mechanism of the Pansy prevents that. The only part of the stigma that is receptive to pollen is a minute hollow spot, and attached to this is a tiny flap which hangs *downwards*. When the bee withdraws her tongue it presses on the flap from underneath and temporarily closes it over the hollow spot. The pollen, therefore, cannot possibly get in. But when the bee, with her tongue still dusted with pollen, visits another Pansy, she finds the flap hanging down and, in thrusting her tongue past it, causes some of the pollen to be transferred to the little hollow. Thus cross-pollination is triumphantly effected.



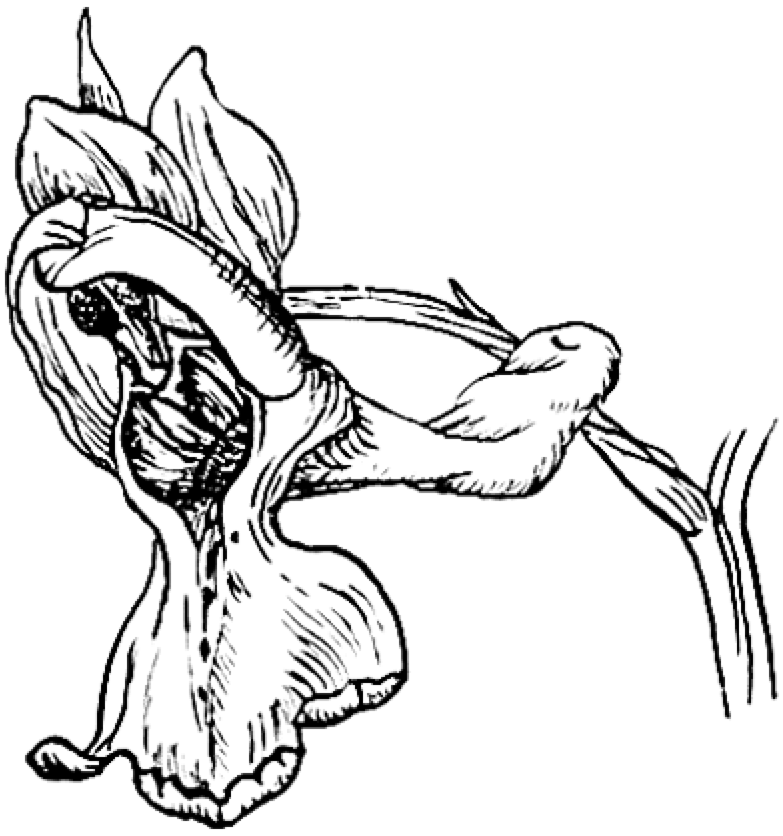
PANSY

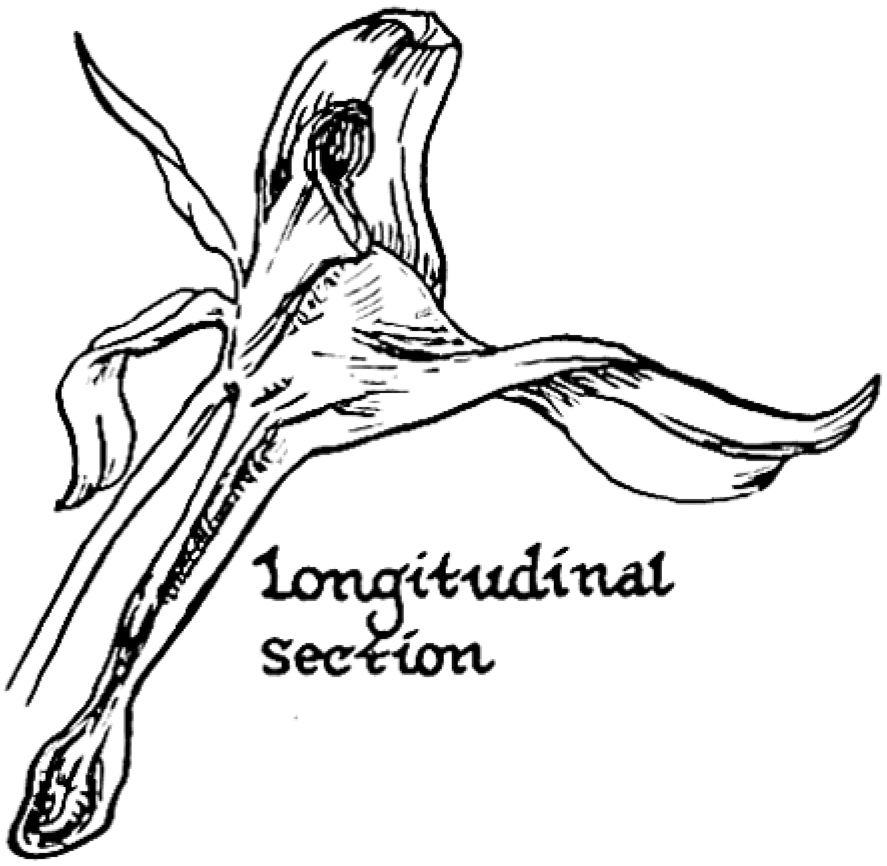


PANSY STIGMA
(GREATLY ENLARGED)

Violets are very similar in shape to Pansies, but, amongst other differences, the flap I mentioned is often absent.

I am not sure that Orchids (which are monocotyledons) are not even more astonishing than Pansies, but you can form your own opinion about that by studying the common Early Purple Orchis. The flower is exceedingly complex—far too complex, indeed, for me to attempt a description—but the essential features for our purpose are the unusual form of the pollen-grains and the method of shedding them. They are held together, by means of sticky threads, to form two jade-green, club-like masses, each of which is joined by a hair-like stalk to a sticky disc. When a bee enters the flower, the two club-like masses of pollen attach themselves promptly to the front of her head by means of the sticky discs, and the creature departs bearing what resembles an extra and unnatural-looking pair of erect " feelers ". But the really astonishing thing about these pollen-masses is that, after about half a minute (which would give the bee time to reach another flower), they cease to stand erect, for the stalks have gradually bent downwards till they are pointing straight ahead. Do you realise what is going to happen? When the bee enters another Orchid the pollen masses will be pointing straight towards its stigma, some of the grains will be left there when they touch it, and the flower, in its own unique manner, will achieve cross-pollination. Push a pencil into the spur of the flower, and then watch the masses of pollen that come away with it, observing

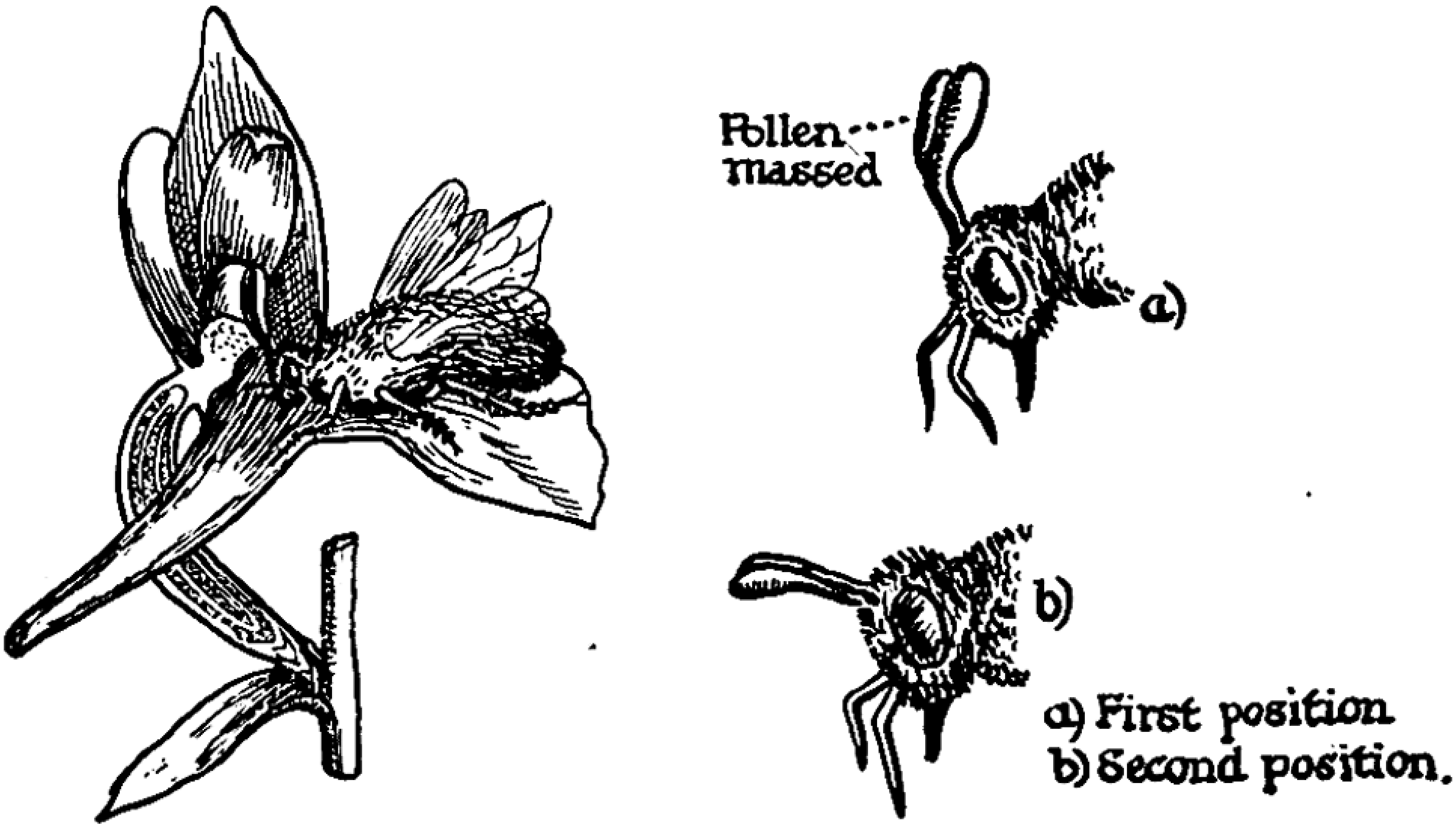

Early Purple Orchis, showing Pollen Masses, Disc and Stigma



Section showing Spur cut open

how they bend forward in the manner I have described. It is one of the most impressive instances of the marvellous adaptations of flowers for securing cross-pollination.

I should like to go on telling you of these wonderful contrivances—of the flowers that are pollinated only at night-time, when all but a few of the living creatures of the world are asleep; of those that never unfold their buds, yet pollinate themselves secretly behind the closed petals; of the Arum, that entraps flies and makes them transfer the pollen as the price of their freedom; of the Primrose, that produces two kinds of flowers to help cross-pollination; of the pollen-baskets constructed by the Eyebright and other blooms to hold their fallen pollen until a bee arrives, and of all the other varied tricks and expedients which are to be found in flowers, all directed to the furtherance of this supremely important work of cross-pollination. It seems a pity that, when there are such interesting things in Nature, you should miss any of them; but we must hurry on to the next part of our investigation, and, if you are in earnest in your study of plants, you must read a good text-book on the subject and, with this as your guide to its many details, wander out into the fields and lanes and learn in the most delightful (and indeed the most essential) way of all from the flowers themselves.

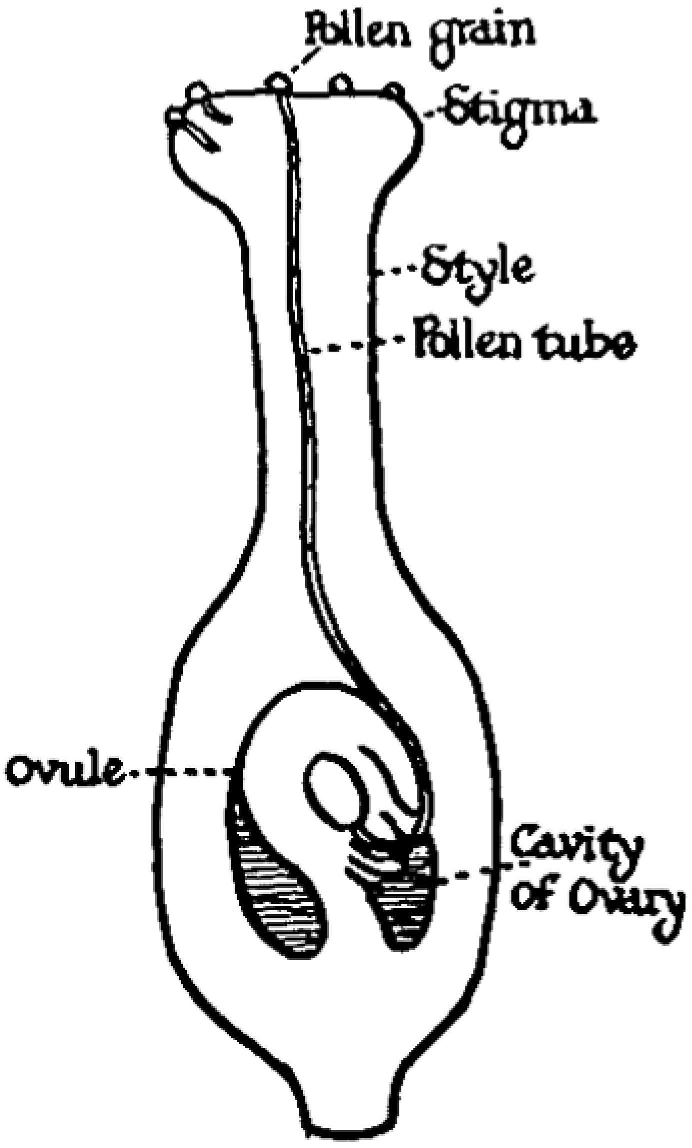


Bee on Orchis

One lesson, none the less, I must dwell on for a moment. You have seen what an important service the bees and other insects render to the flowers in pollinating them, and you have learned how the flowers in return reward them by providing the nectar and surplus pollen on which they live. Here, then, is one of the most striking instances of the wonderful harmony of Nature, in which two distinct classes of her children work together for mutual advantage.

Meanwhile, after a somewhat lengthy and roundabout journey, we have seen the three ways in which flowers are commonly pollinated. The first way (self-pollination) is when the pollen simply falls on to the stigma of its own flower. The second and third ways (cross-pollination) are when the pollen is transferred from the anther of one flower to the stigma of another by the wind or by an insect. We have seen, too, that, even when the wind or an insect is employed, self-pollination may occur, but that the flower usually does its best to prevent it. We are now in a position to follow the final stage of the journey which, as you may remember, must be made to bring the pollen-grains into contact with the ovules lying enclosed in the ovary. In so doing it will be brought home to us that, however much it may please the bees and other insects, the prime purpose of pollen production is to develop the ovules into seeds. In whatever manner pollination is effected, the subsequent behaviour of the pollen-grains lying on the stigma is the same; and, although this is perhaps the most vital period of the plant's existence, it can be described quite briefly.

The pollen-grains themselves remain on the stigma, feeding on the sweet liquid which it exudes. Then, strangely enough, they begin to grow, each one putting forth a thread-like tube. The tube grows in length and, piercing the stigma, begins to travel slowly down the inside of the style. Presently it emerges at the lower end to find itself in the dark cavity of the ovary. As if guided by some compelling instinct, it makes its way to one of the ovules attached to the wall or some other part. Do you remember the little hole we discovered in the Broad-Bean seed? That little hole exists in each ovule of a plant long before it becomes a seed, and in most cases it is towards this that the lengthening pollen-tube is attracted. The tip of the tube enters the opening, some tiny particles of vital substance escape from the tube into the ovule. One of them meets another tiny particle there—the egg-cell—and unites, or fuses, with it. The flower is *fertilised.* From now onwards a secret activity stirs in the egg-cell. Mysterious movements and strange changes take place, and then in time we begin to discern the growing shapes of an infant root, a stem and bud and seed-leaves, such as we saw in the seed. The fertilised ovule has, in fact, become a *seed*, containing within its coat the elements of a new living plant. Thus are the long labours of the flower crowned with success.



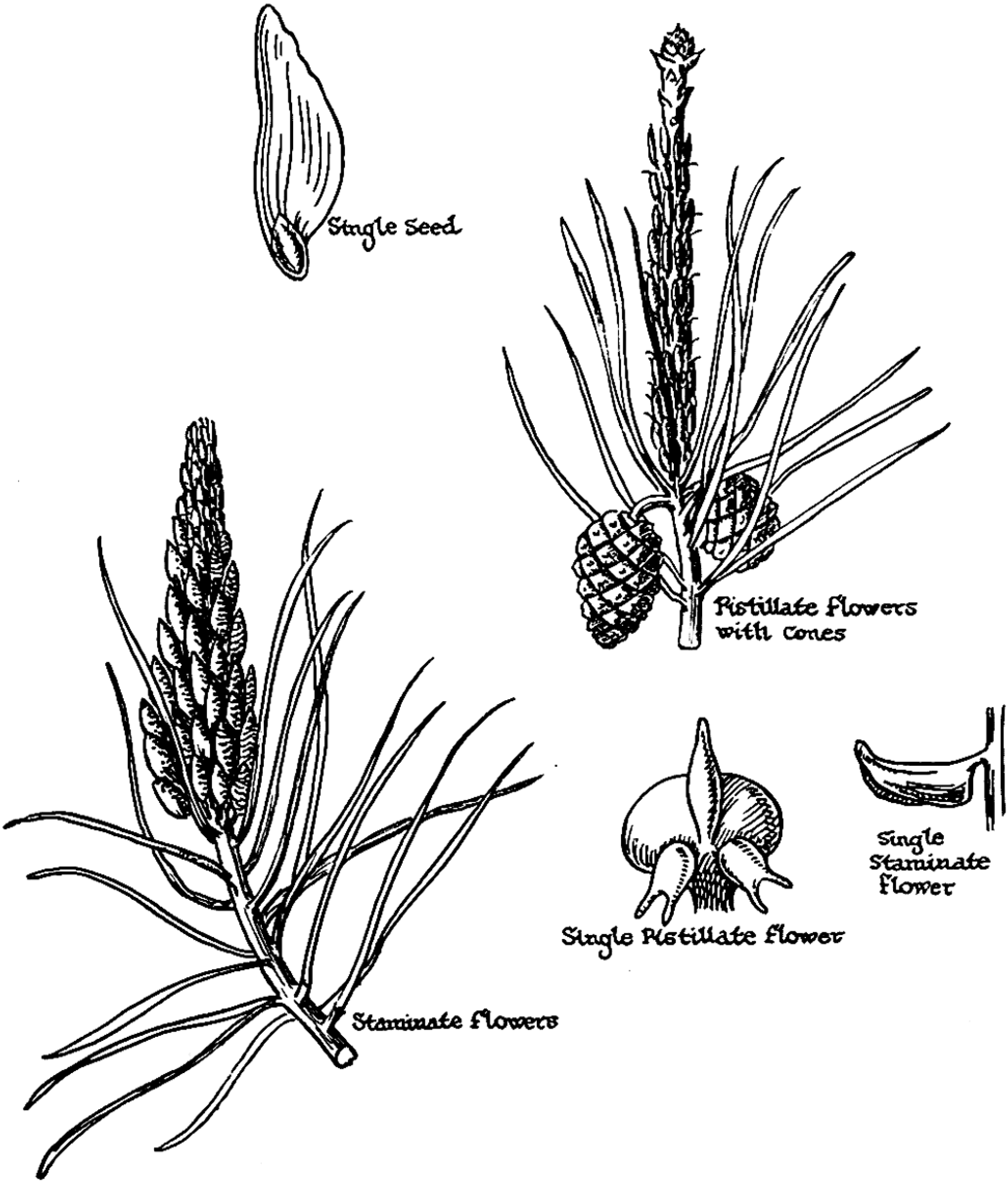
Germination of Pollen Grain

And now I think we may safely leave the seeds to rest for a while in the ovary while I tell you a story or two. The fragrant odours which Roses and Lilies, Violets and Jasmine and other favourite blooms produce to attract pollinating insects are not always allowed to fulfil their intended purpose. Human beings are as greatly attracted by them as the bees, and so we step in and, by various processes, extract the delicious essences to scent our clothes, our persons and our toilet requisites. There was once—so the story says—a Sultan of an Eastern land who, like all his subjects in that torrid climate, was greatly given to the pleasures of the bath. One day his favourite Sultana thought she would please her lord by filling the bath, which stood out of doors in the palace gardens, with rose-water. Now, the fragrant essence that we call attar (or otto) of Roses exists in the petals in the form of minute globules of oil. The globules in the Sultan's bath of rose-water rose naturally to the surface and became concentrated, under the rays of the blazing sun, into considerable patches. One of the Sultan's slaves observed this and, fearing that it was some impurity in the water, began to consider the safety of his head if his master should discover it. So he hastily set to work and skimmed off the oily scum. What was his astonishment when he found his nostrils assailed by one of the most fragrant and refreshing odours conceivable! Running to the Sultan, he told him of his discovery, and from that time the attar was carefully collected, and became the most highly prized of all perfumes. And the discovery that it took anything up to three thousand pounds of Rose petals to yield a pound of the finest attar did not lessen its value. Nowadays there are acres and acres of special kinds of Roses cultivated in India and Persia, besides France and other European countries, for the sake of their perfumed produce.

Another story has to do with the unusual character of the stigmas of the Saffron Crocus. The flower resembles in some ways that of our Meadow Saffron. It is a native of the East, but has long been cultivated in England, and indeed run wild in some localities. The tale is told that the plant was first introduced into our country six hundred years ago by a pilgrim from the East. The Pilgrim stole a corm (you remember what a corm is?) and hid it in a hollow which he scooped out in his staff. Then he stole out of the country at the peril of his life; "for if he had been taken, by the law of the country . . . he had died. . . ." When at length he landed safely in England, he planted the corm at the town of Walden in Essex. There the plant came to be cultivated extensively for the production of saffron, and it was in that way that the town received its present name of Saffron Walden.

The saffron product, which we still use to a limited extent in medicines and for colouring and flavouring cakes and buns and pastry, consists of the orange-red stigmas of the flowers, which are dried and pressed into solid slabs. In olden days, from the times of the Greeks and Romans onwards, saffron was much more extensively used and was held in the highest esteem. It afforded a valuable dye, which was reserved for the garments of kings and nobles. Its aroma was deemed so refreshing that the essence was set flowing in little streams at entertainments or sprayed over the heads of the guests. For centuries saffron formed an important ingredient in a large number of medicines and was eaten as a spice with food. In fact it was regarded as such a refined delicacy that one ancient writer declared it to be the principal nourishment of the fairies. As to that I don't know, and I am inclined to ask how the writer himself knew.

You will readily understand that a vast number of plants


Single Seed
Pistillate flowers with cones
Single Pistillate flower
Single Staminate flower
Staminate flowers

Scots Pine

would need to be robbed of their stigmas to make up a fair-sized slab of saffron, and indeed it is said that, when Queen Elizabeth visited Saffron Walden and the Town Corporation presented her with a pound of saffron enclosed in a silver cup, no less than forty thousand blooms were required to supply it.

There is one more thing I have to tell you, and then, after I have given you some outdoor occupation, we will go on to the story of the seed. There is a group of trees and shrubs whose flowers differ markedly from those we have been examining, in that they do not enclose their ovules in a cosily protective ovary. The most familiar of these plants are the cone-bearing trees, such as Scots Pines, Firs and Larches. These trees have two kinds of flowers, the staminate flowers being massed in one kind of catkin and those containing the ovules in another. The flowers are scarcely worthy of the name, for they are nothing but scales and anthers in the one case and scales and ovules in the other. Although the ovules have no ovaries to protect their infant forms, they are not altogether exposed to the mercy of the elements. The scales to which they are affixed overlap one another in the catkin, like the slates on a roof, and so afford them a sufficient measure of protection. The ovules are fertilised in just the same way as those of the other types of flowers, the pollen being carried to them by the wind; but the tube of the growing pollen-grain finds the little opening in the ovule without being put to the trouble of penetrating a stigma and then travelling all the way down a style. Later on, the catkins bearing the fertilised ovules develop into the well-known cones. In Somerset the children call the cones of Pines and Firs " Mountebanks ", " Johnny Mountains " and " Dolly Mounters ", though I have not the faintest idea why. They also call them " Oysters " because the scales are supposed to resemble them, and I presume the attached seeds represent the pearls that are found in some oysters.

Now, by way of a new kind of experiment, I will give you a surgical operation to perform. Open up several flower-buds that contain both stamens and pistils—*e.g.*, Buttercups—but do not remove them from the plant. Carefully snip away all the stamens, without damaging the other organs, and then tie a fine muslin bag over each bud. The flowers cannot now pollinate themselves or receive pollen from another flower. Watch the subsequent behaviour of your patients, and notice whether they ever mature their ovaries and set seed. Then you can draw your own conclusions about the necessity of pollination. To prove that the failure to produce seeds was not due to the mutilation of the flowers, you can yourself, a day or two after you perform the operation, collect (on a fine, soft brush) some pollen from other flowers of the same kind and transfer it to the stigmas of a number of your victims, replacing the muslin bags when you have finished. The flowers so treated will, in the ordinary course of events, duly set seed.

Study the flowers described in this chapter and make large-scale drawings. Cut some of them down the middle and sketch the exposed (vertical) sections. Examine the anthers of flowers when they are splitting open and shedding their pollen. Follow the operations of bees, flies and other insects that visit flowers and try to imagine the various ways in which they effect self- or cross-pollination.—And observe a thousand other intriguing features that this chapter will suggest to you.

CHAPTER X

ADVENTURING OUT IN THE WORLD

I SAID that the labours of the flower were crowned with success in the production of the seeds, but that does not mean that those labours are finished. There is still work to be done, and that of the utmost importance, though the most conspicuous organs of the flower will usually take no part in it. After a time petals and sepals, stamens and style and stigma for the most part wither and fall, their task fulfilled, though in many instances some of them remain to see through to the end the task of carrying on the race.

When the ovules are fertilised, the succeeding changes are by no means confined to those vigorous infants. While the resulting seeds are increasing in size and hardening their coats, the ovary in which they are set undergoes important developments. It may increase enormously in size. Its walls may become tough or hard, or even woody; they may become dry, or swell out into a sweet, fleshy mass; and they may take on the most vivid colours. In fact, a mature ovary may change so completely in appearance that it is difficult to believe it is the same vessel we saw in the flower. The final outcome of all these changes is called the *fruit*.

"Oh, yes, of course," exclaimed Janet when Uncle Fred explained this to us, "apples and oranges and pears."

"And dandelions," added my uncle quietly, "and parsnips and grounsel and peas and beans and——"

"But, Uncle, peas and beans aren't fruits—they're *vegetables*," declared Janet, and for once I agreed with her.

But we were wrong, as my uncle proceeded to explain. Every flowering plant, he told us, produces its fruit. That fruit consists essentially of the mature ovary with the ripened seeds within; though the term is often made to include as well any parts of the flower—*e.g.*, the calyx, or the style, or even the expanded top of the flower-stalk—that habitually remain attached to the mature ovary. It is only in popular language that we limit the word to particular fruits—such as apples and plums—which are eatable. Of course, after learning this, you may be sure that Janet seized the first opportunity of catching me napping by saying she had some scrumptious fruit for me, and then making me close my eyes and thrusting some fluffy (and prickly) Thistle-heads into my hand.

When my uncle took us out into the lanes and showed us the curious and varied shapes of the fruits of different wild flowers, and explained the reason why they developed their numerous peculiarities, we realised that plants had not exhausted their surprises in the adaptations of their flowers. The fruits, we decided, were equally intriguing, if not more so. I want to repeat those rambles in your company so that I can pass on to you what I learned, both then and later. But first I must say a word about the construction of fruits in general, so that, when we study those of particular types, all of which have their distinctive names, you will understand them better.

You may remember that, in the last chapter, I explained that the ovary of a flower might have one or more chambers containing the ovules. This is true also of the resulting fruit (though not in all cases); for the fruit, as you have just read, is essentially the mature ovary with the ripened seeds within. You must understand, however, that not all the ovules in the ovary become seeds, for great numbers of them never develop.

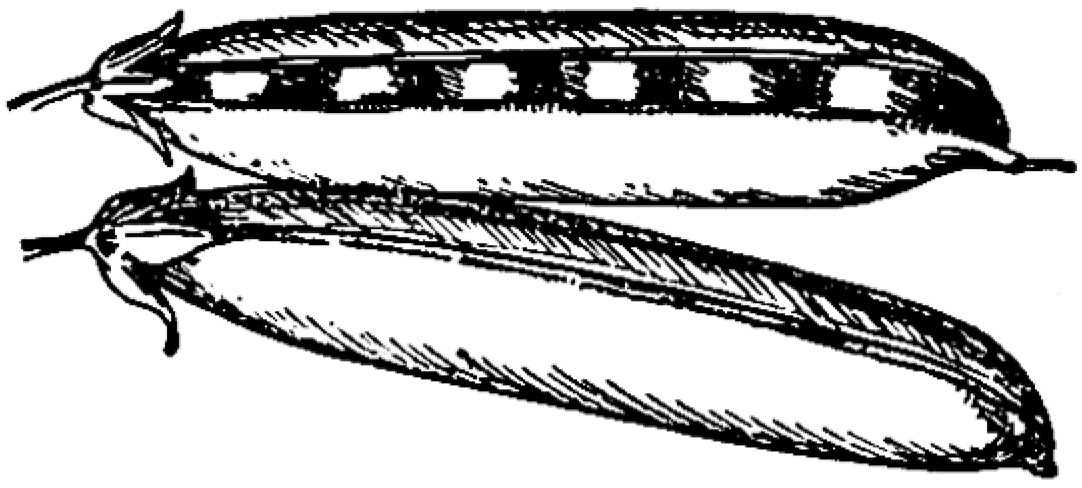
Now, before we actually put on our hats and set out, let us pause for a moment and take stock of the position we have—or rather the plant has—arrived at. As the result of its steady vital activities, it has successfully produced some seeds which are shut up in a box for protection. That is excellent progress, but obviously it is not the final goal. For one thing, the seeds must be let out of the box. For another, they must be placed in surroundings favourable to their germination. The first of these requirements is, of course, quite obvious, and it is easily fulfilled. Either the fruit-wall splits open while the fruit is still on the plant, or the fruit is detached entire. In that case the fruit-wall gradually decays, or it is burst open at the time when the seed germinates. We shall see presently how birds and other animals forward some of these processes, but meantime we will consider the second requirement I mentioned.

I wonder if you have any notion of the number of seeds a plant may produce: that a Sunflower may have more than a thousand, a single Poppy-head perhaps fifty thousand and a Mullein-spike a trifle of seven hundred thousand or so? I amused myself once by trying to calculate the number of seeds on a Mullein I found growing vigorously from a crack in the wall of a tumbledown stable. There were 435 separate fruits on the spike, and the largest of them contained, as nearly as I could tell, 710 minute black seeds. Even if you take the average number of seeds in the 435 fruits at 600, you get the respectable total of 261,000; though, as I have indicated, this falls far short of the maximum of which the plant is capable. Certain other plants are so prolific that the Mullein seems comparatively sterile. One kind of Orchis has been reported to produce seventy-four *million* seeds on each plant; while Darwin calculated that the great-grandchildren of a single Spotted Orchis, in the impossible event of all the seeds of each generation germinating, would cover the entire land-surface of the globe. Now suppose the entire multitude of those hopeful infants simply tumbled out of their nurseries and fell in a heap to the ground at the foot of the parent plant. How many of them do you think would survive in the fierce struggle for existence that would follow? Obviously only a very small proportion. The remainder would be snuffed out of existence, and even the few that did succeed in establishing a hold on the ground would find their lodging so crowded, and the available supplies of light and air and food so limited, that healthy growth would become all but impossible. That is the chief disadvantage of producing new plants by means of bulbs and corms and similar methods; the infants are too closely crowded around their parent.

Plants, then, have been " forced " to realise that some better plan is needed than the simple one of dropping their seeds at their own feet. They must *shoo* them out of the crowded and unhealthy " city " there and let them loose into the open " country ", where there is room to grow and multiply in their turn. They must *disperse* their seeds.

Now I think we are ready to start out and, by examining some of the more common types of fruit, discover how the plants achieve this final aim.

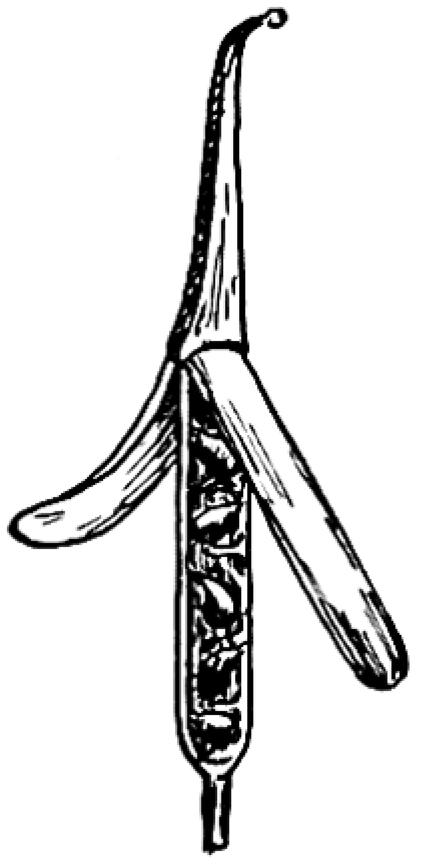
The first common type of fruit I want to show you is that of the *pod*. Garden Peas are familiar instances, and you can guess that the pod itself has developed from the ovary of the flower and the eatable " peas " from the ovules, which are now, in fact, the seeds. There is not, as far as I have ever noticed, anything particularly striking in the way these seeds are released. The pod splits open and the contents merely fall to the ground, or are shaken out by the wind; though we usually pick them long before they reach that stage. Other fruits of this form will afford us more entertainment. Suppose our walk takes us over a heath, where the Gorse, and perhaps the Broom, are flowering. If the weather is hot, we may be puzzled to hear all around us a succession of tiny reports suggestive of an exchange of artillery fire by the pixie-world at war. Investigation, however, will disclose that the guns which are going off so rapidly are not in the hands of the " little people " (you must never mention the pixies by name, folks say, or they will play some mischievous prank on you), but on the Gorse and Broom bushes. The heat of the sun is drying up the pods and causing their tissues to contract unequally. A moment comes when the pods fly open with a pop, twisting themselves up in the violence of the explosion. And with that twist the seeds are flung out, to be scattered all around, it may be several feet away.



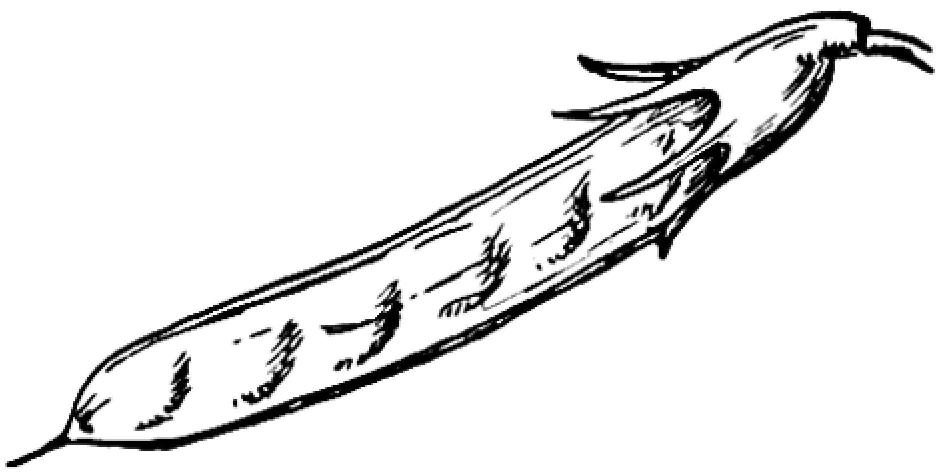
" POD " (OR LEGUME) OF GARDEN PEA

Janet declares that the Gorse must have rather a peppery temper, it is always flying out so. It bombards the bees with its pollen and then, to scatter its seeds, it simply blows itself up. However that may be, you can study the latter process at home by putting a tray-full of the pods on the stove. Presently they burst with quite a startling *Crack!* and leap into the air one by one like trout after the May-flies, twisting up in their flight as if they were contortionists. The seeds, however, mostly remain in the pod, and, if you want to see them ejected, the pods must be fixed (with clips for instance), as they are on the growing bush. You will be interested to compare their behaviour with that of the Sweet Pea pods in your garden, for the latter behave in the same manner.

Many plants have pod-like fruits that are divided into two chambers by a thin partition on which the seeds are set. The Wallflower, as we have already seen, is one of them, and it is quite interesting to watch it when it is preparing to loose its seeds. As the pod dries, the outer walls of the two chambers separate *at the base* and gradually curve outwards and upwards, leaving the seeds exposed on the thin central division. Then, when they are ripe, a puff of wind obligingly carries them off, their thin, flat shape helping them to travel quite a distance.



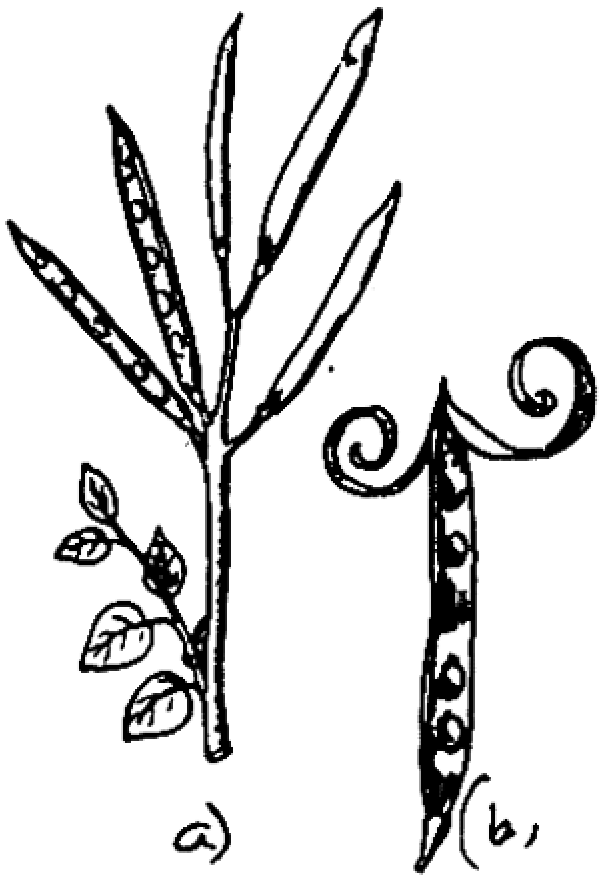
WALLFLOWER "POD"
(OR SILIQUA)



BIRD'S-FOOT TREFOIL "POD"
(OR LEGUME)

The Bittercresses have a similar fruit, and Janet and I discovered its extraordinary mechanism one day quite by accident. We were playing cricket in a meadow beyond our garden, and I had just swiped a lovely ball right over to the far hedge. Janet ran after it and flung herself on to the bank—and there she stayed. I saw her brushing her hand over the grass, and then heard her laugh gleefully. She seemed to have forgotten all about the game, and anyhow I think she was sick of it, for she hadn't been able to get me out for ages. I yelled out to her, but the aggravating little monkey took not the slightest notice, so in the end I had to trot over and see what she was doing. When she heard me approach she didn't condescend to look up, but shouted out, "Mind yourself or you'll get shot."

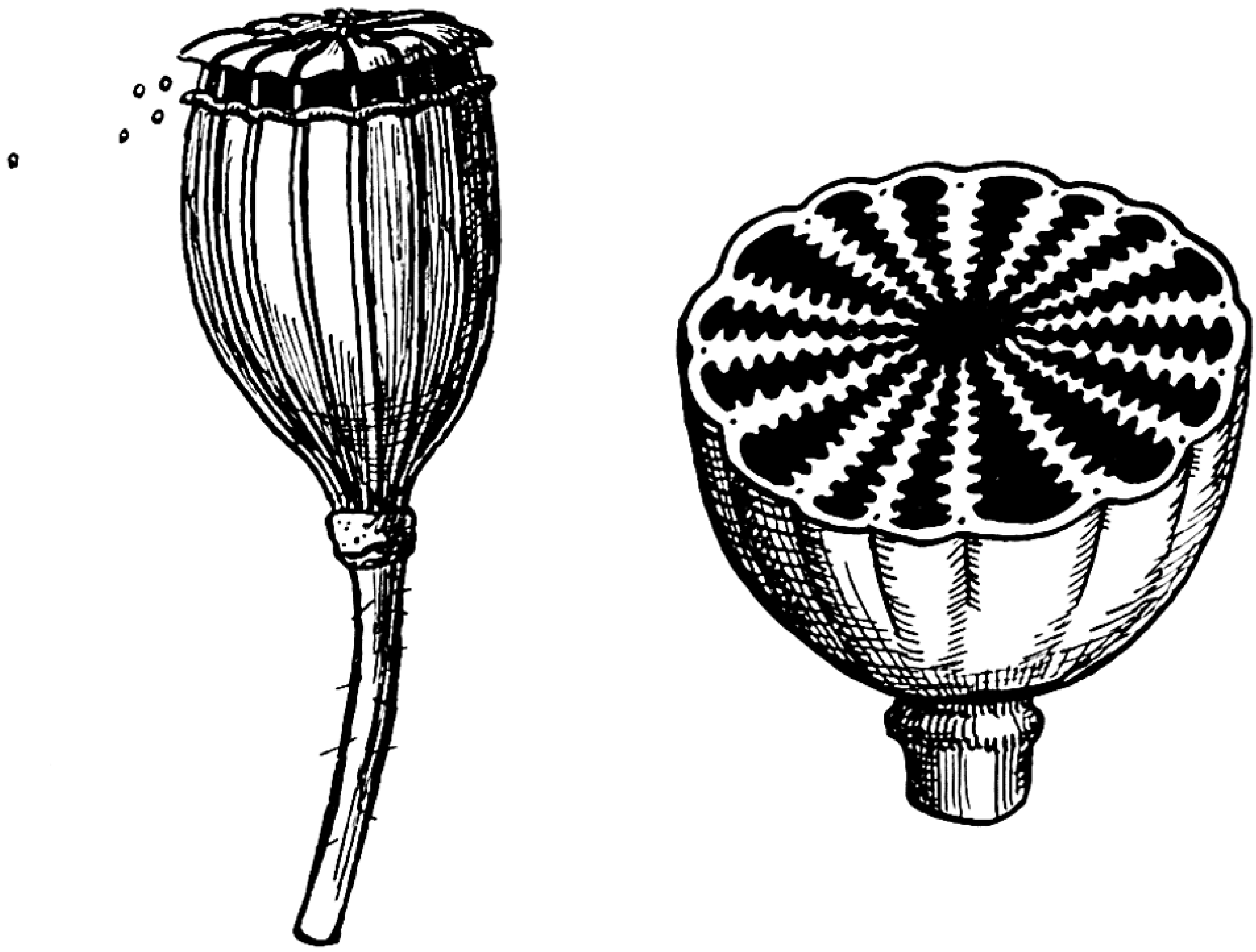
"Shot!" I exclaimed scornfully. "What *are* you talking about?" and I flung myself down on the bank beside her. At the same moment she swept her hand over the grass right under my nose, and I felt my face peppered with a discharge of very small shot, as if I was Gulliver under fire from the Lilliputians. Well, it was odd, and we amused ourselves brushing the grass in each other's faces for quite a while, and then began to look for the source of the firing. We didn't make it all out there and then, but later on Uncle Fred pieced out what we told him, and it appears that the shot was the seed of a crowd of unnoticeable little plants called Bittercress that grow thickly on hedgebanks and waste places. The fruits, which grew in upright clusters, were just like those of the Wallflower, but much smaller, and at the lightest touch their two outer walls curled up on either side of the central partition like lightning. Sometimes they remained at the top like a pair of ram's horns, but more often they simply leaped up into our faces in tight little coils. At the same time the flattish, yellow seeds were flung out all over the place till the air seemed to be alive with them. It was great fun.



BITTERCRESS
(*a*) Cluster of fruits. (*b*) Single fruit (enlarged).

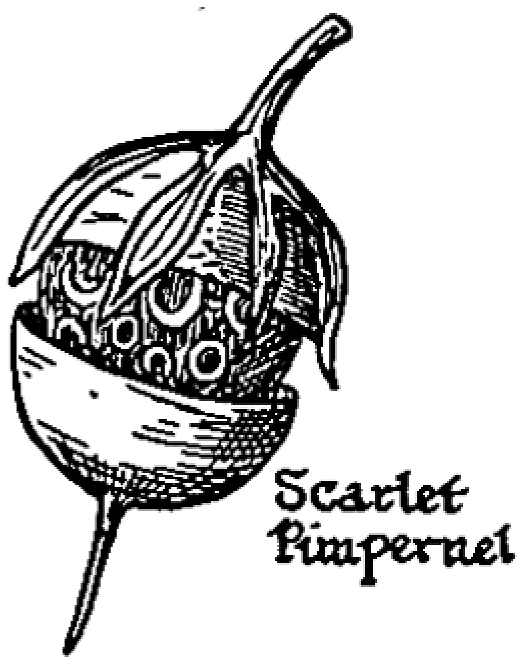
Pod-shaped fruits of different kinds are found on a lot of other common plants—Shepherd's Purse, Lady's Smock, Rest-harrow, Clovers, Trefoils, Vetches, Charlock and so on—and you can learn a little more about them by reading Chapter XII. One plant in particular, though, fascinated us, because its fruits were so exactly like a bird's foot. This, as you will guess, was the Bird's-foot Trefoil. The clustered pods spread out exactly like the toes of a bird's foot, and the remains of the styles supply them with the most convincing claws.

The next kind of fruit we will talk about is that known as a *capsule*, a word which means "a little case". It has a great variety of shapes—all developed from the ovaries—but more often than not it is more or less globular or oval. It may contain one or more chambers to hold the seeds. We need not travel far to find a form to study: the first cornfield we reach will provide us with an especially interesting one in the flaunting Poppies. Poppies always have painful associations for me. They bring back the times when my mother used to steep the heads, or capsules, in boiling water and make me inhale the steam for my raging toothache. Apart from that, however, I can appreciate that, in designing them, Nature seems to have lingered to give her work an elaborately ornamental finish. The capsule is a beautifully rounded goblet or cup closed in with a flattened top that projects like the eaves of a roof. This roof is decorated with a number of ridges arranged like the spokes of a wheel, the ridges being actually a very unusual form of stigma. Snugly sheltering beneath the overhanging eaves is a ring of open windows. If you slice off the roof of this delightful little dwelling, you find that each window looks down into one of the numerous chambers of the capsule, and that these chambers, which all communicate with each other by means of a sort of central lobby, are filled with

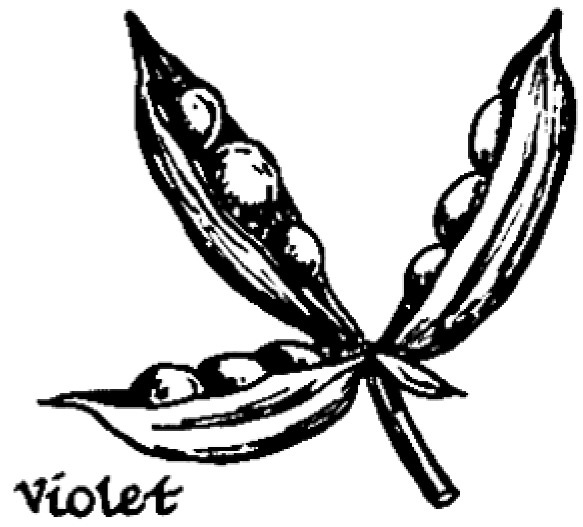


Poppy Head

countless small powdery seeds. The stalk on which the capsule is poised is stiff and wiry, and a high or gusty wind sets it jerking up and down. This is all to the good of the plant, for, as a result, the fine seeds are gradually shaken out of the circle of open windows and borne some distance off. Harebells and Snapdragons shake their seeds out of the window in a similar way, though the openings are differently situated. Many other plants, having no windows in their capsules, are helped none the less by the wind in dispersing their seeds as the fruits rock to and fro. The capsules split open along the sides, as in Bluebells and Foxgloves; or at the top in so many teeth, as in Primroses, Stitchworts and Campions; while the Plantains (whose spikes are always welcome to our canaries) and the dainty little Scarlet Pimpernel split crossways, the top opening like the lid of a box.

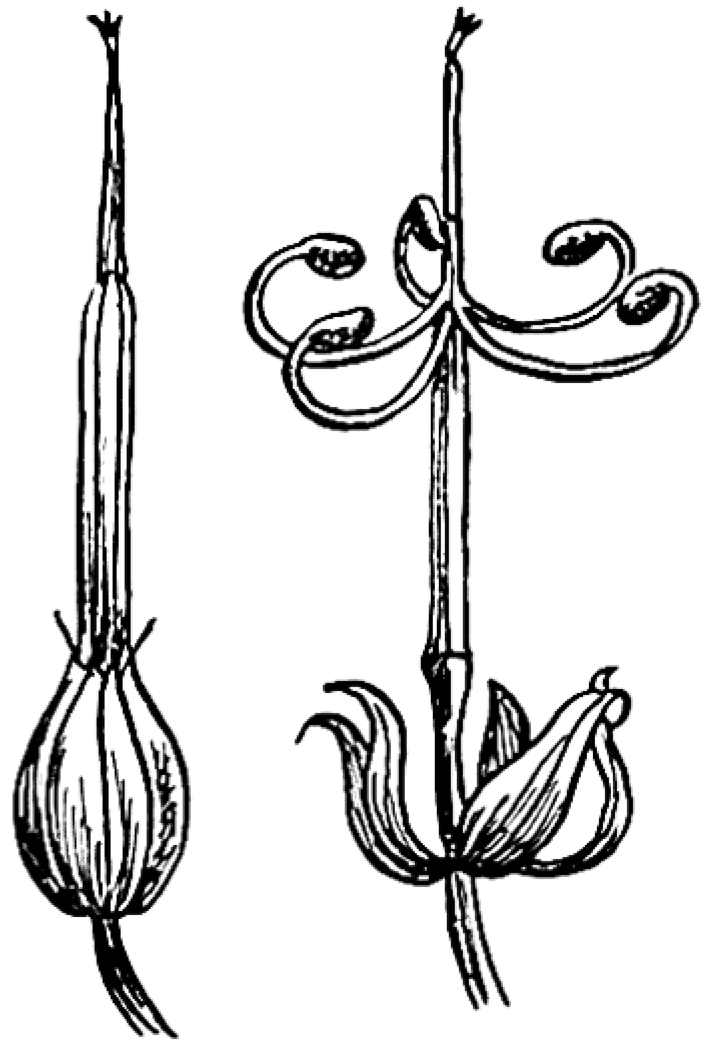


SCARLET PIMPERNEL CAPSULE



VIOLET CAPSULE

When a gardener wants to save the seeds of particularly choice varieties of Pansies or Violets that have rejoiced his heart, he sometimes ties muslin bags over the plant. This seems a funny thing to do, and it certainly has an odd effect in the garden, but the conduct of the plants drives the gardener to it. The capsules, in drying, split into three little boat-shaped parts, each laden with a cargo of seeds. Then the two sides of each boat gradually close up as they shrivel and, in so doing, they squeeze the seeds. These seeds are smooth and slippery and, of course, as a result of the squeezing, they are flicked out into the air (just as you might flick an orange pip), and come to the ground perhaps several feet away. The Crane's-bills are another set of plants sometimes given to violent habits in dispersing their offspring. The capsule is in five parts (each containing one seed), and these parts are grouped round, and attached to, the base of the long, pointed " bill " that gives the plant its name. When ripe, the parts separate, and each tears off a thin strip from the base of the bill and springs up and out with such elastic force that the seed is often shot out quite a distance into the air. It is a distinctly forceful way of sending one's children out into the world, and it reminds me of the Seagulls, who ruthlessly push their young over the edge of the cliff where they nest, in order to make them learn to fly. The Stork's-bills adopt a somewhat similar method to that of the Crane's-bills, but they go even farther. The seeds themselves are not flung out of the fruit, but the parts into which the latter splits are detached from the plant entire. The strips which they tear off from the bill are set with fine hairs, and the strips themselves curl up like a corkscrew during wet weather and uncurl again when the air is dry. The effect of this is to force the fruits into the soil, where the seeds will eventually germinate; but there is often another effect which, to us at all events, is rather unexpected. The fruits creep along the ground as the strips curl and uncurl and so move away a short distance from the parent plant. Lay some of them, in a moistened condition, on a piece of paper and, if you are patient, you can watch the uncanny creeping performance going on.



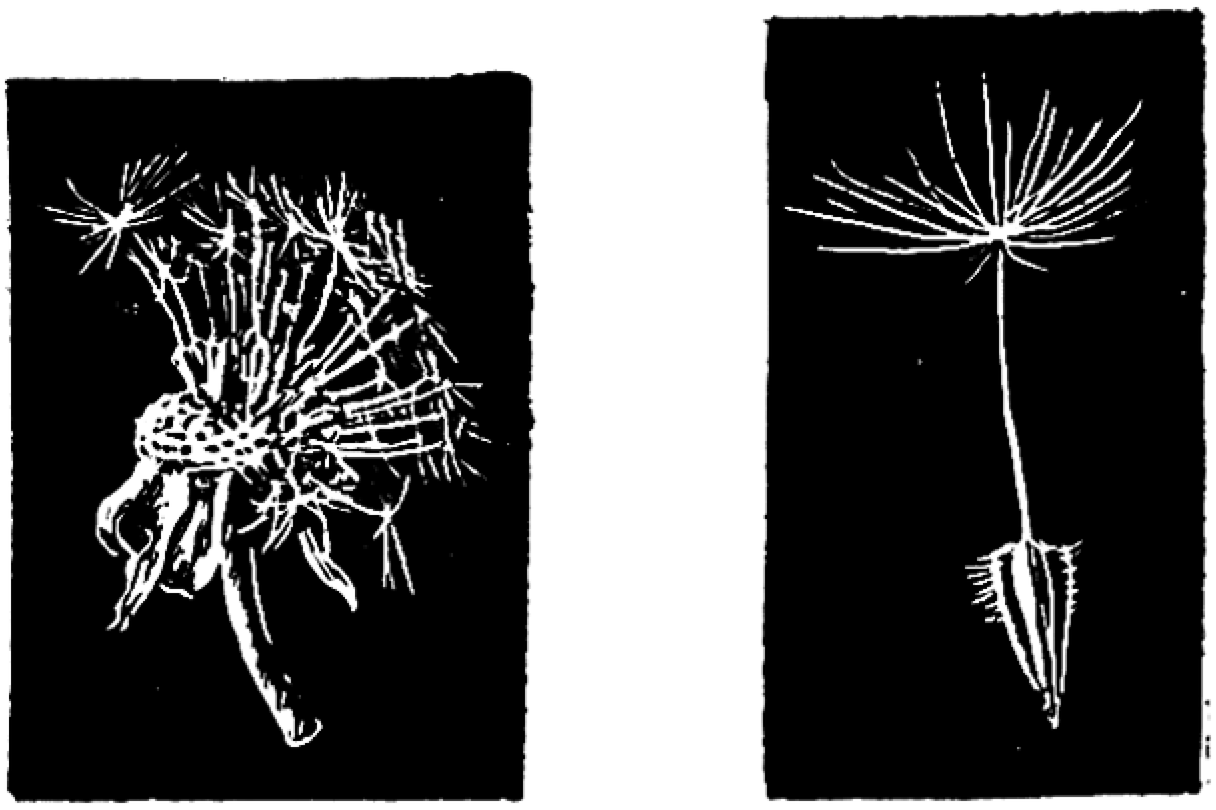
Capsule of Wild Geranium
(Crane's-bill)

We must look at one final example of the catapulting system in the fruit of the shy little Wood Sorrel, that hides its winsome beauty in the shady corners of woods and hedge-banks. The capsule is divided into five chambers, with two shining seeds in each, and the chambers open by the splitting of their walls. Should you happen to touch one of the capsules when it is quite ripe, you may be not a little astonished to find your fingers the centre of a small bombardment as the seeds shoot out through the slits. Consider the matter a little, and you will want to know what force it was that expelled them so abruptly. The explanation will bring you to another discovery. The seeds are covered with an extra coat of a highly elastic character. When a seed ripens, the coat breaks open at a certain point. Then, before you can say *knife !*, it suddenly turns itself completely inside out and the seed is catapulted through one of the slits in the capsule out into the world beyond, sometimes for several yards.

During one of our rambles Janet and I happened to be trying to tell the time by a Dandelion " clock ", when it suddenly came into my mind that parachutes might well have been invented by someone who had just been watching Dandelion fruits sailing through the air. I confided my brilliant idea to Janet, and she burst out laughing in my face. But Uncle Fred didn't laugh when I asked him about it. He said it was quite a good notion, though he didn't think there was anything in it. None the less it set us studying the flower, and really it was most mystifying to observe how the parachutes appeared on the plant, seemingly from nowhere at all. Because, you know, you look at a flower-head one day and see it as a golden disc formed of scores of massed florets. A few days later you look at it again and the golden disc has vanished with the withering of the petals. You think that all life has passed from the sad-hued object that was once so radiantly colourful. Then a greyish-white, downy mass shows within the innermost of the two rings of long, green, leaf-like organs, called " bracts ", that have come to form the most noticeable part of the head. And then, as time passes, if you happen to give the thing another glance, you discover that it is completely transformed. The lengthened stalk of what was once the flower-head stands boldly up, as if arisen from a trance-like sleep, and proudly displays its new creation—a globe of airy down that rests lightly poised at its summit, as if on the tip-toe of flight.

How is the miracle performed—the miracle we scarcely ever think about because it is so common? I cannot tell you what sets the train of events in motion. All I can do is to describe briefly the changes that occur in the closed heart of the flower-head from the magic moment of the fertilisation of the ovules to the production of the ripened fruits. On the top of the minute ovary of each of those massed florets is set a ring of fine hairs attached to the ovary by a short neck. The hairs take the place of the calyx in ordinary flowers (this is one of the surprises that plants are always springing on us) and, now that the fruiting time is come, they stand in an upright tuft ready to perform a special duty reserved for them. The neck grows into quite a lengthy and stiffish stalk, carrying the tuft upwards. The same growth is taking place in all the florets of the head, with the result that the withered petals and styles and stamens are pushed off in a tawdry mass and the whole collection of tufts emerges as the greyish-white, downy mass I spoke about.

Everything is now ready for the final flight, except that the children must be given a good take-off for their adventurous journey. The short, hollow flower-stalk, which has previously lain close along the ground, lifts itself up and lengthens out until it overtops the surrounding grass and stands free of all obstacles that might foul the coming take-off of the aerial squadron lightly borne at its head.



Dandelion Parachutes

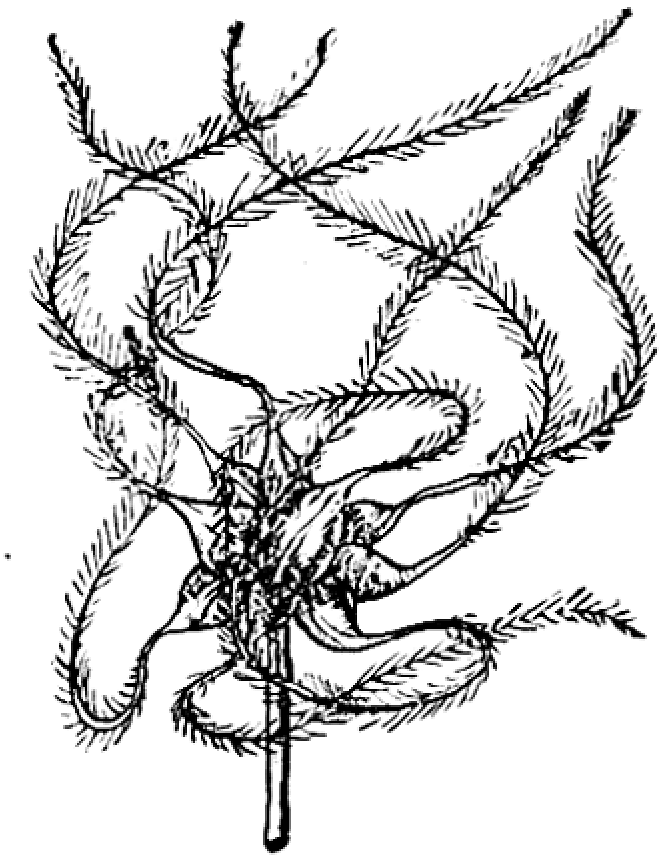
And now both circles of the protective bracts of the head have fallen back and hang downwards, *their* part of the common task performed, and you see the white ball of down—the " clock " —take shape. It is worthy of a little scrutiny to discover how it is made. The ripened fruits are massed on the rounded head of the flower-stalk. (They are actual *fruits*, you might remember —of a kind called *achenes*, containing a single seed.) From their tops spring the stiff stalks that bear the tufts of hairs. But the tufts have now flattened out to form horizontal wheels of gossamer, and thus the fruits are suspended by perfectly formed parachutes.

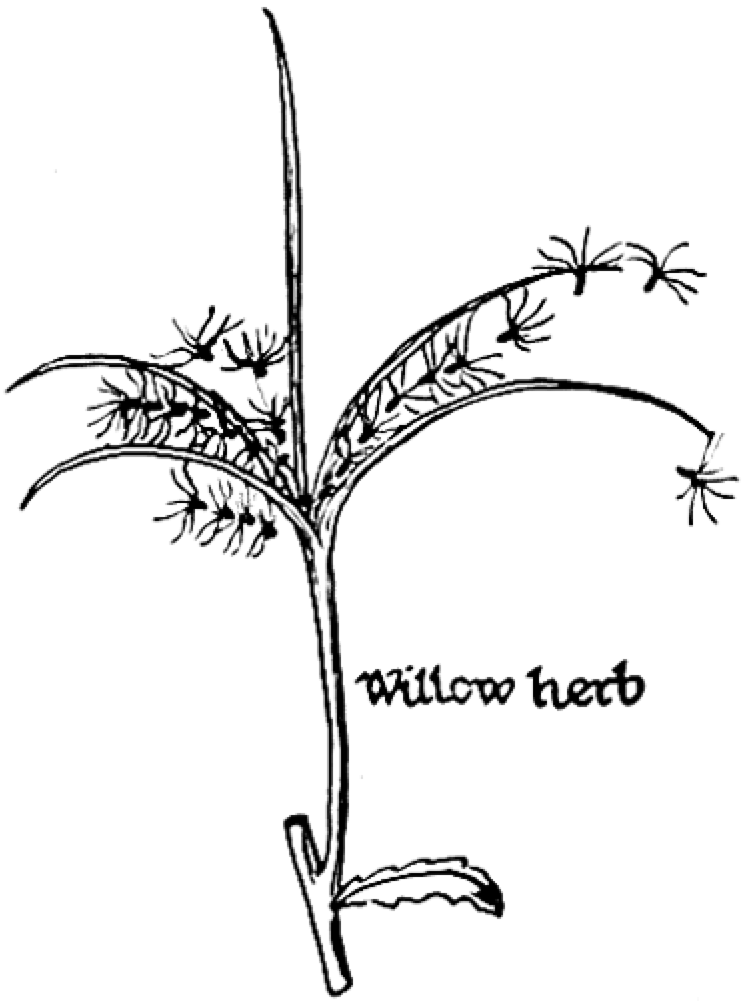
And the parachutes are arranged on the head of the flower-stalk in a radiate manner, standing out quite regularly in every direction, so that the wheels of down touch each other at their rims, and thus form a perfect sphere. The lightest wind will break the fragile ball and send the separate parachutes sailing away with enviable ease upon the warm air, till the suspended fruits make their landing after a flight that may be short and uneventful or long and crowded with perilous adventure by the way.

There are hosts of flowers which, like the Dandelion, equip their fruits with hairs to aid their dispersal by the wind. You can study the details in which they resemble, or differ from, the Dandelion in Colt's-foots, Groundsel, Goat's-beards, Knapweeds, Cornflowers, Hawkweeds, Thistles, Ragworts and other plants. If it were only true, as the old fable says, that witches used to fly to their midnight assemblies on the stalks of the Ragwort, what an incomparable means of seed-dispersal that would afford the plant! Imagine the downy fruits floating away, as the witch careered in mid-air, and scattering themselves over an area of miles! But, on the other hand, think of the number of fruits of Thistles and such-like plants that were born in vain—from the plants' point of view—because people gathered them as down for filling pillows. You will notice that, in some of the flowers I have mentioned—the Goat's-beard and a number of the Thistles for instance—the hairs are branched and feathery, to give even further buoyancy. Hold a partly opened head of the Spear Plume Thistle before a fire and, as the fine, feathery hairs separate, you will see a fairy-like forest of silver grow up before your eyes.

There are times when the organs of a flower will take on some duty which is not normally expected of them. You have seen how the calyx of the Dandelion, in the unusual form of a ring of hairs, persists on the fruit and helps to waft it away. Evidently it found the common duties of a calyx rather dull and felt itself fitted for higher things. At any rate—so we may fancy—it thought it would be more exciting to be a parachute, and a parachute it became. Now look at the Clematis or Old Man's Beard and the ragged down with which it decks itself in autumn. Each flower of the plant has numerous *separate* ovaries, each with its style and stigma, and, when they ripen into achenes, the whole collection is treated as one *compound fruit*. Buttercups, Lesser Celandines, Strawberries and Roses are other instances of a compound fruit. In the Old Man's Beard, the styles of the flower, which are feathery, refuse to decay and fall off with the petals in accordance with custom, but persist after the fruit is formed, thinking, no doubt, that they can make themselves useful. And they certainly justify their obstinacy, for they grow out to an extraordinary length, so that each collection of achenes becomes involved in a feathery mass—the old man's beard—and this is seized upon by the wind, with the result that the attached fruits become widely dispersed.

Sometimes it is the seeds themselves that are tufted instead of the fruits, the soft down wrapping them round as they lie within the fruit walls. As I sit at my window to-day the air is filled with a fleet of downy seeds sailing from a line of Willow trees growing along the river-bank. They have escaped from the split capsules and, buoyed up by the long, silky hairs affixed to their base, travel gracefully on through the warm summer air, to what distances I cannot tell; but so many of them are floating through the open window that I am forced to close it. Poplar seeds have similar tufts at their base, while those of the Willow-herb bear them at the top.


FRUIT OF CLEMATIS, WITH ACHENES AND FEATHERY STYLES



FRUIT OF WILLOW-HERB

When a gardener has sown a row of seeds, he thins out the resulting seedlings to give the remainder room for healthy growth. Try the experiment of sowing, first, a few small seeds, well spread out, and, secondly, a much larger number, close together, in separate pots of soil. Then observe the relative growth of the individual seedlings in the two groups.

Try to count the number of seeds contained in various pods, capsules and other fruits.

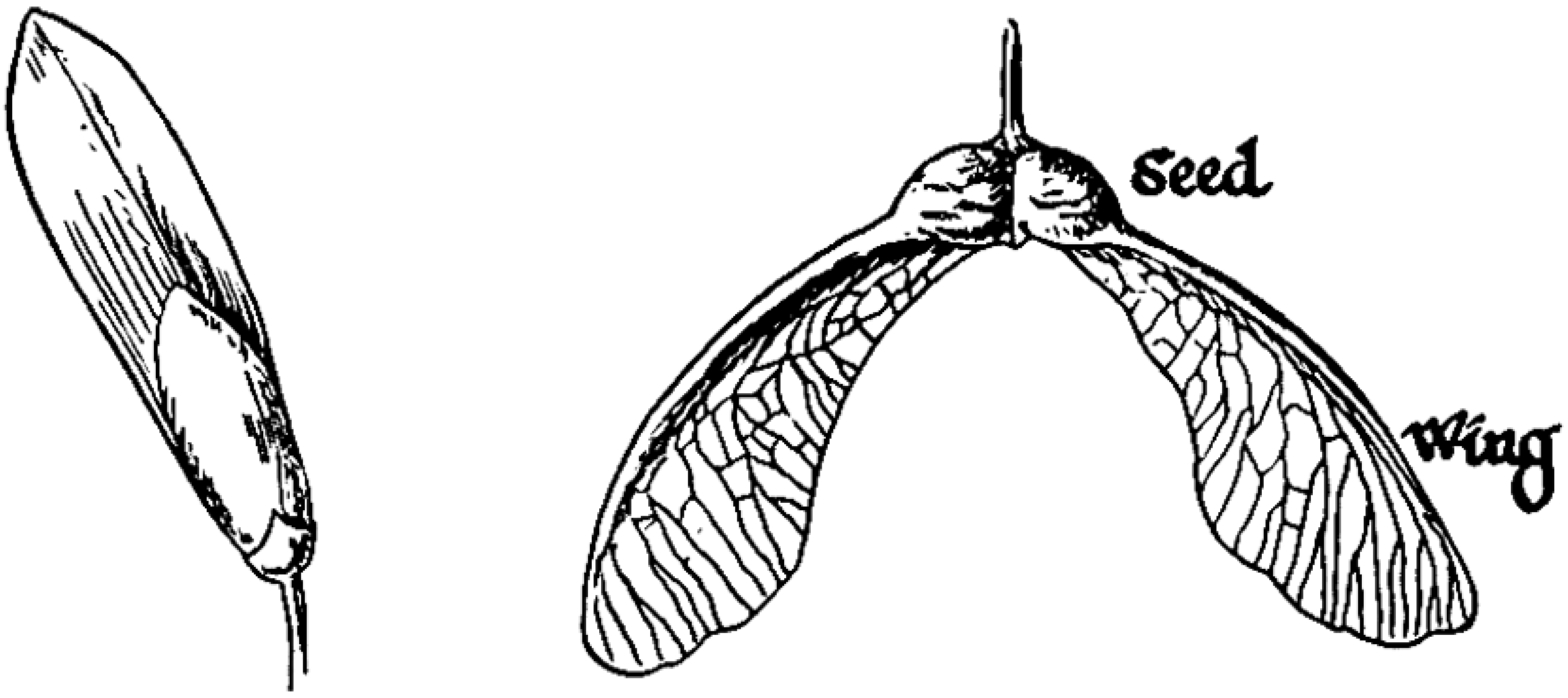
Study the changes in the ovaries of different flowers up to the ripening of the fruit, noticing the diverse manners in which the fruit-walls split. Make a collection of fruits and draw them on a large scale. You will learn that some of them—*e.g.*, the Poppy—make beautiful designs.

CHAPTER XI

NUTS AND APPLES AND SIMILAR THINGS

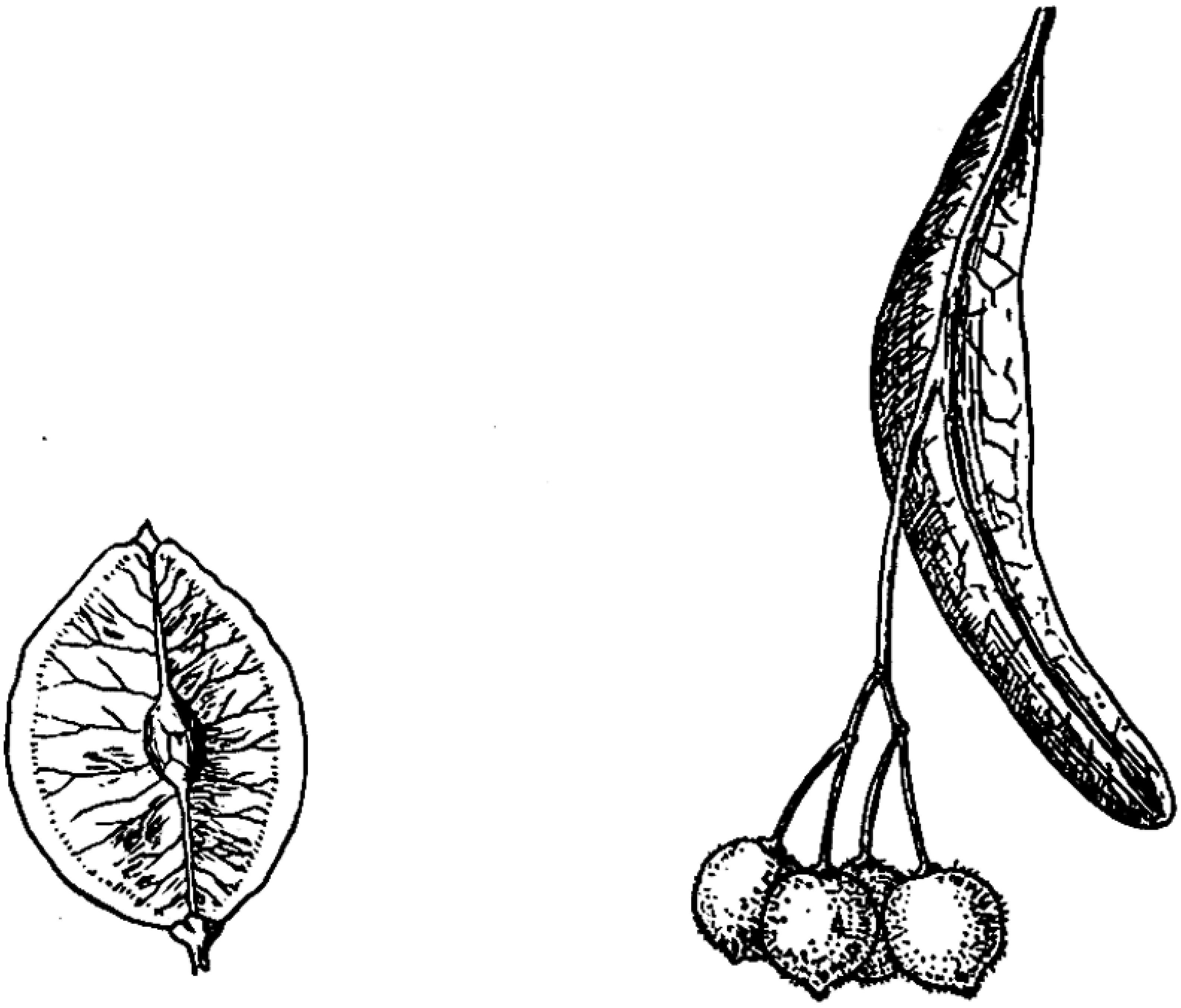
MANY of our trees look with disdain on such flimsy attachments as hairs as an aid to flying. After all, they declare, if you want to fly, the sensible thing is to grow wings. And so they grow wings—by expanding the fruit-wall into a thin, flat outgrowth—and I wish we could do the same. In the Ash these winged fruits, or " keys ", hang in dense clusters from the branches, each fruit containing, usually, a single seed. The long wing is often twisted to give the fruit a spin and keep it afloat longer. Country children call them " Spinners ", and in the bad old days, when people believed in witches, a bunch of Ash-keys was supposed to protect you from their evil attentions. The Sycamore fruit has two (sometimes three) parts, each containing one seed, and each bearing a wing fashioned like a bird's. It has a stout shoulder at the top with numerous fine veins running out from it to keep the parchment-like blade firm and taut. The parts of the fruit separate before they leave the tree, each flying off on a single wing. When we found some on the ground during our excursions we had great fun throwing them up into the air and watching their behaviour. They spun round at an astonishing rate, exactly like gyroscopes, and remained poised in the air for quite a long while. And, of course, the longer they spun, the farther the wind carried them. They really are most fascinating things, and the name of " Aeroplanes " which very up-to-date children give them is entirely appropriate.

Elm fruits grow in bunches that change from green to brown as they mature. Each fruit is like a small, oval plate with the seed set somewhere near the centre. Actually it is embedded in the plate, and the latter forms a wing all round it. Ever since Janet ragged me about finding butterflies in Birch trees I had been keen to discover them for myself. She kept saying that what I



Ash

Sycamore



Elm

Lime
Here the wing is
developed from a bract

Some Winged Fruits

really deserved from the tree was a close acquaintance with the birch they used to make from its twigs for use in school, and she taunted me with a line from some old play she had read somewhere:

> And now the burchin tree doth bud, that makes the schoolboy cry.

At last with Uncle Fred's help, I was successful in my search, and I am bound to admit she had a certain amount of justification for her ridiculous assertion. The catkins of pistillate flowers grow into pendants of tiny, one-seeded fruits. Each fruit looks like an incredibly small butterfly, duly fitted with wings; but what completes the extraordinary resemblance is the pair of curling " feelers " (the remains of the long stigmas of the flower) attached to its head. In autumn the fruiting catkin is gradually broken up by the wind and the butterflies take wing. I do not, however, think they often fly far, for you can find them in crowds at the foot of the parent tree.

The sweet-scented Lime tree, whose honeyed flowers are a murmurous haunt of bees, showed us a new kind of float. The fruits are small nuts which usually contain one seed, and they hang down in elegant clusters. The stalk of each cluster is attached to a long, leaf-like bract, and this acts in the manner of a kite, supporting the fruits for a time as they fall from the tree. The Hornbeam, too, disperses its fruits with the aid of a bract, though it is fitted in a different way. The tree is more generous than the Lime, for it furnishes one bract, each with three lobes, to every individual nut in the fruiting catkin.

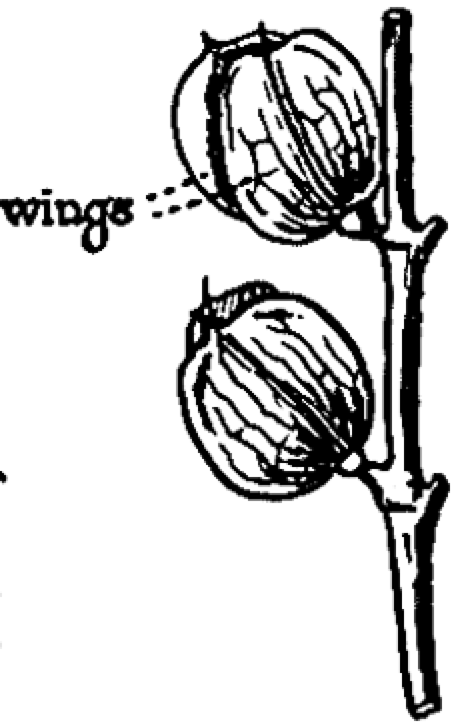
The Scots Pine (like the Larches and some of the other cone-bearing trees) has winged *seeds*. There is nothing you could term rash in the pace of the fertilising and fruiting processes, for it may be a matter of two years from the time the pollen is received before the ripened seeds escape from the cone. During this lengthy interval, however, the seeds have been slowly preparing for flight, acquiring a long, thin wing to carry them out into the world.

Some of the humbler herbs equip their fruits and seeds with wings, though they are not as a rule so striking as those we have been considering. You may look for them in the fruits of the Docks and the seeds of the Yellow Rattle, the Spurrey and the

Toadflax. When Darwin visited New Zealand a hundred years ago he found Docks growing in the greatest profusion. It appears that the seeds had been palmed off on to a planter as Tobacco-seeds and sown by him in the fond expectation of raising a valuable crop. Alas! for his hopes when day by day he watched the growth of the prolific alien weed.

Every step we take in our study of fruits and seeds emphasises the importance which plants attach to the problems of their dispersal. You know what a lot of plants arm themselves with annoying hooks, but you may not have realised that, when these are attached to the region of the fruits, they serve to scatter them. Think of the Burdock. Its heads of fruits, or burs, are surrounded by a dense covering of bracts whose sharply pointed ends bristle like the bayonets of a line of infantry "preparing to receive cavalry"—only here the bayonets are hooked. The slightest contact brings away the entire bur on to our clothing, or on to the bodies of the cattle and the furry rabbits and other wild creatures that browse in the hedge-banks. We ourselves pluck them off as soon as we discover their unwelcome presence, but in the very act of throwing them to the ground we are doing what the plant intended, for we are obediently scattering the fruits for them. As Janet says:

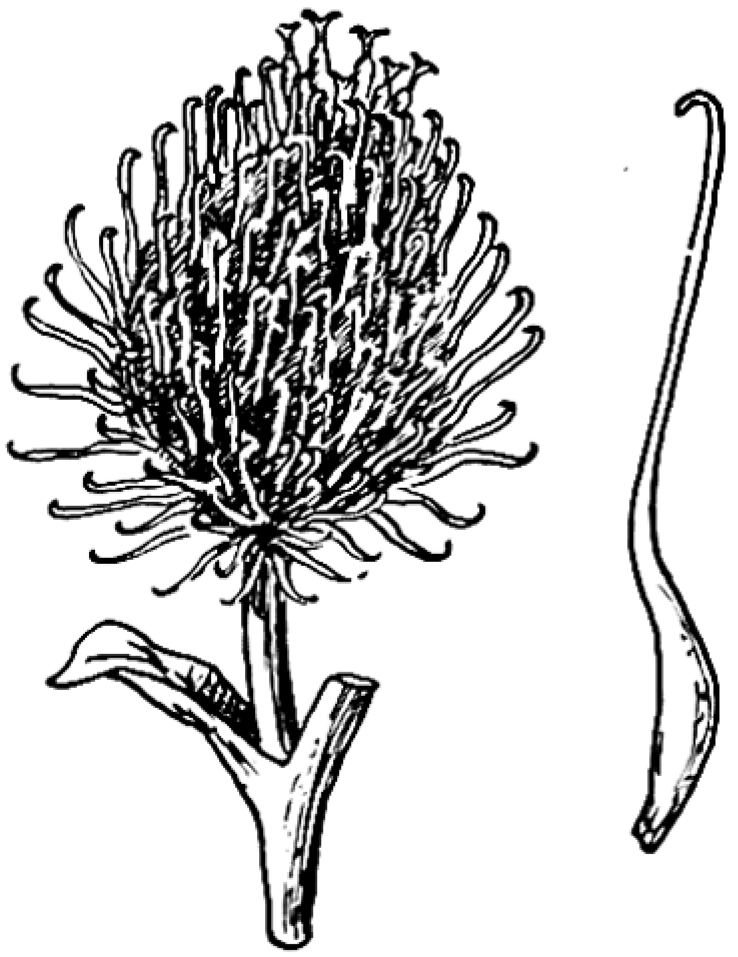
They jump aboard and ride on us
As if we were an omnibus.



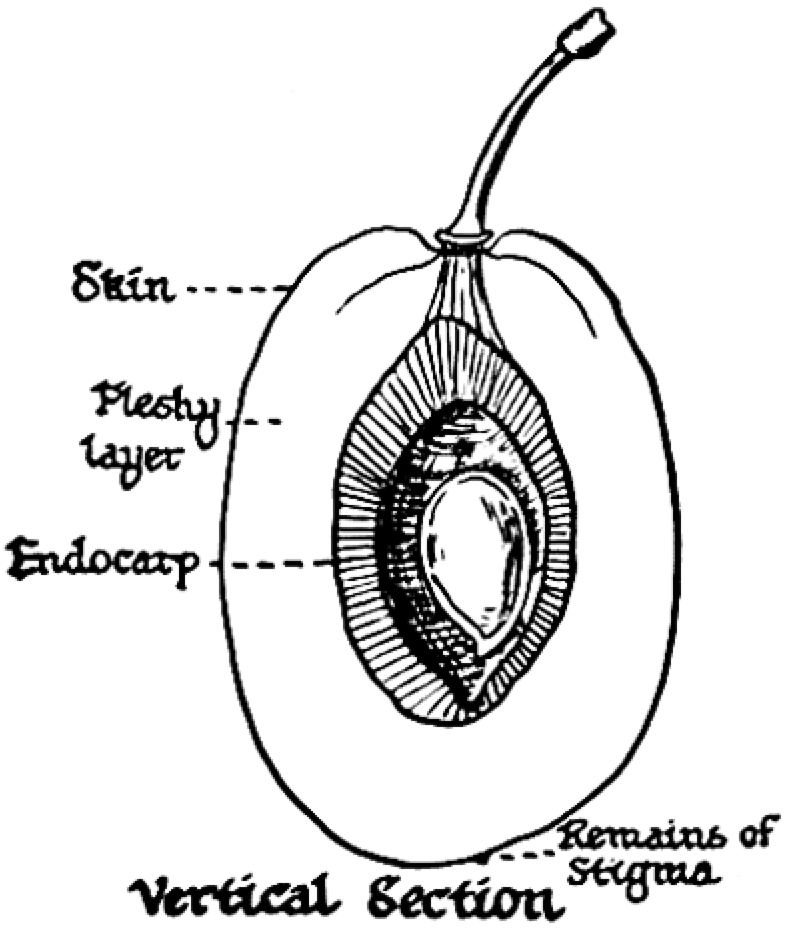
YELLOW RATTLE FRUITS

But what has always been a mystery to me is how the Burdock "knows" that we shall be passing by, or in fact that we exist in its world at all. A mystery of another kind is how country boys have come to believe that they can catch bats by throwing Burdock fruits at them.

The Goose-grass is covered all over—leaves, stem and fruits—with hooked bristles. The fruits themselves form small green burs, and, as they are less noticeable than the large burs of the Burdock, they get dispersed far more widely. No wonder the plant is called Cleavers, for it cleaves to us in the most persistent and affectionate manner, as if it had been waiting for us a long time as old friends and could never bear to be parted from us again. It quietly takes its seat in the train, as it were, not bothering to buy a ticket, but only hoping that its free ride will be a long one. Many a time have I had to tackle the tedious task of picking off the persistent burs in hundreds from the long coats of my two spaniels after they had spent an ecstatic morning rabbiting. " Spick " submits to the process in evident enjoyment; but " Span " finds it fully as irksome as I do, keeping up a succession of pitiful whines and turning up her milky brown eyes at me in passive reproach. The pretty little pear-shaped fruits of the dainty-flowered Enchanter's Nightshade are similarly beset with hooks. Some plants are more sparing in their production of these grappling-irons. In the flower of the Herb Bennet, for instance, each of the numerous ovaries has a long, hooked style, and these remain on the achenes of the fruit, forming a bristly ball whose long, stiff claws catch readily on to any passing animal.



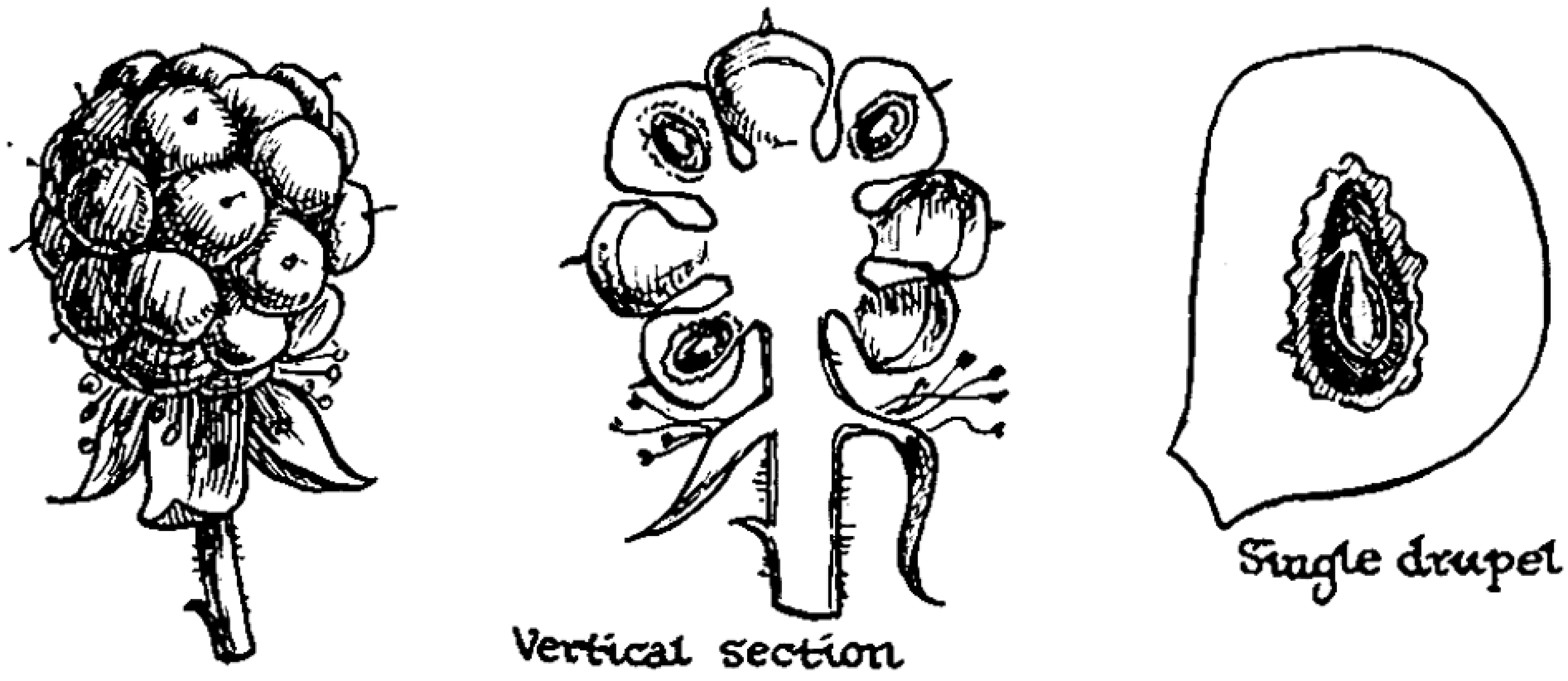
Burdock Bur and (enlarged) a Single Hooked Bract



Plum
Endocarp = stone

Such are a few of the plants whose fruits go a-travelling about the country by the simple expedient of getting a lift from chance passers-by. There are many more of them, and you will find it full of interest to examine for yourselves the various ways in which the hooks are produced. In particular I recommend you to study the Agrimony, Corn Buttercup, Bur Marigold, Woodruff and Wild Carrot.

In following the travels of the winged and hooked fruits and seeds we have unavoidly wandered from our own path, which was intended to lead us to the principal types of fruit in turn. We can, however, now return and consider some of the types which are more in accordance with the poplar notion of a fruit. These, you will find, amply support what I said some time ago about the ovary of a flower becoming so completely changed during the development of the fruit that it was difficult to believe it to be the same vessel. Suppose we take, to begin with, the type known to botanists as a *drupe*, selecting a plum as our first example. Here you will most certainly fail to recognise the ovary, though you may forget all about that in your appreciation of the delicious object into which it has turned itself. The matured ovary has, in fact, developed three " layers " of incredibly different character. The first is the thin outer skin of the plum, the second is the eatable fleshy part and the third is neither more nor less than the hard stone. The seed itself, the " kernel ", wrapped in its thin, brown coat, lies securely within the stone. Cherries and peaches and the sloes of the Blackthorn are drupes, formed in the same surprising way. Raspberries and blackberries are compound fruits composed of a collection of small drupes, called *drupels* or drupelets, formed from the numerous separate ovaries of the flower, and containing each a single seed.

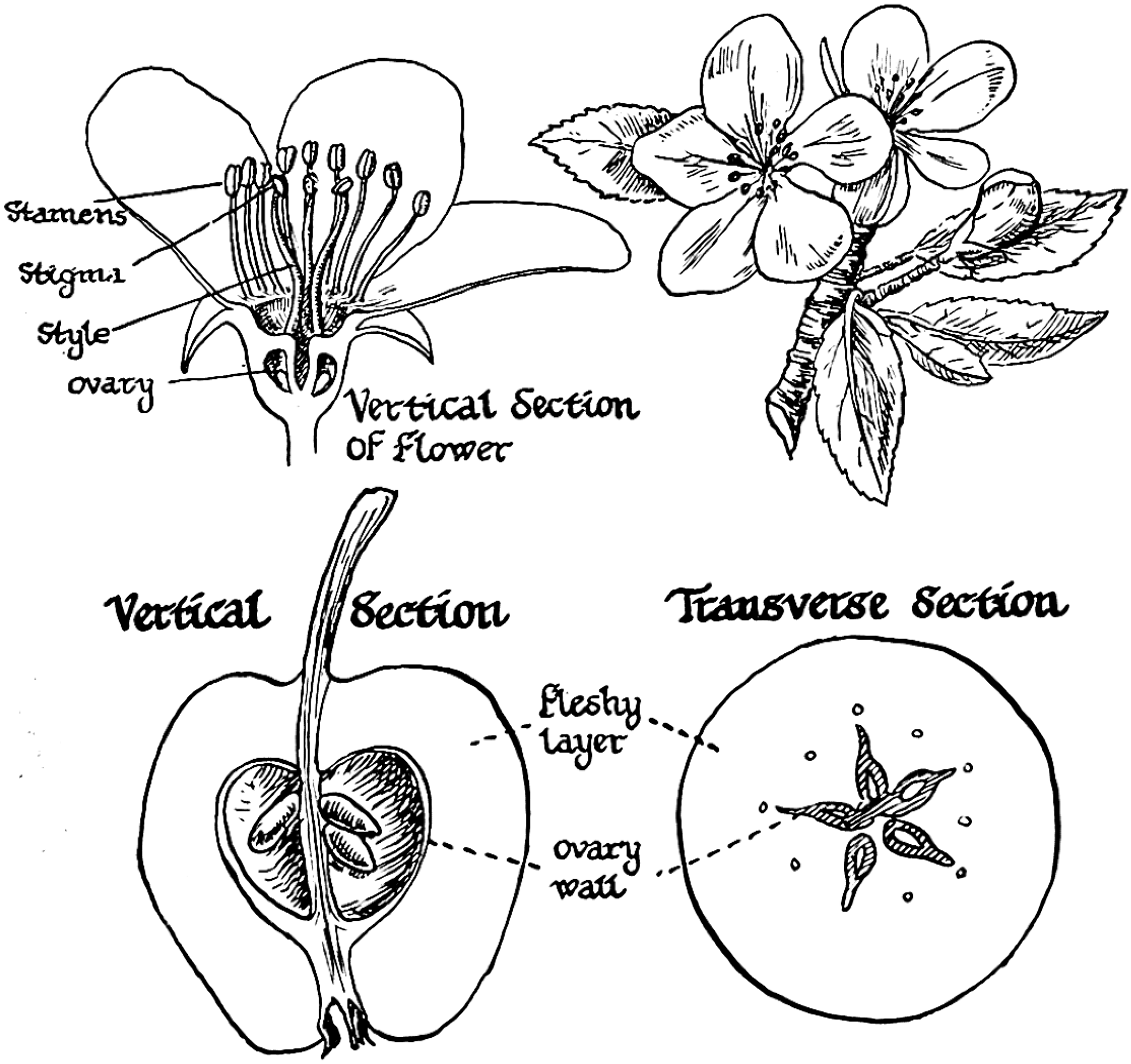


Vertical section

Single drupel

BLACKBERRY DRUPELS

Next comes the *berry*. In this type the matured ovary does not form the stony layer found in the drupe, but remains fleshy throughout. The " pips ", or seeds (of which there are usually several), may have a hard covering, but here it is usually the seed-coats that are responsible for it. Gooseberries, currants, tomatoes, and grapes and even oranges, lemons, pomegranates and cucumbers, develop in the same manner, and, because of this,



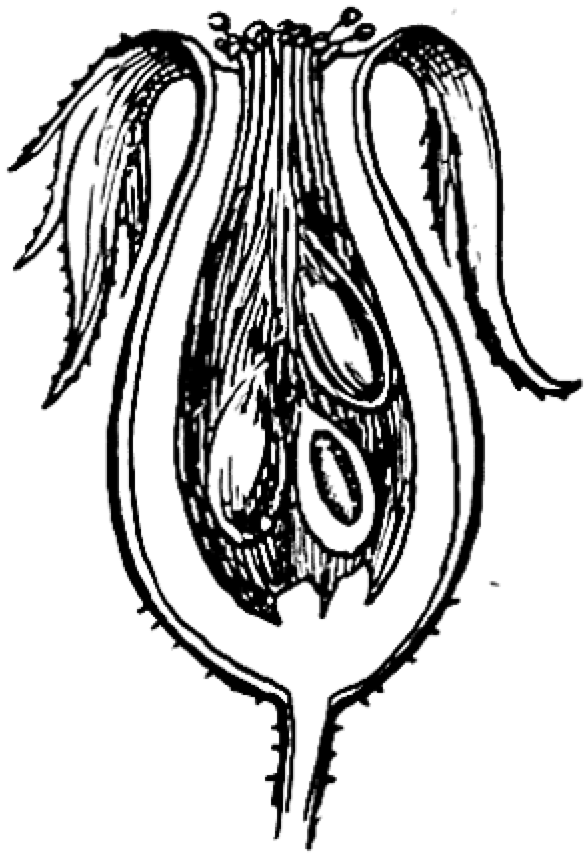
Apple Flowers and Fruit

botanists class them all as berries. They do not in the least accord with our notion of berries, and of course it would be ridiculous in ordinary converse to speak of an orange as " a nice juicy berry "; but in botany, as in all sciences, you must classify objects according to fixed rules. Many of the berries I have mentioned have special features which make them even more curious. In oranges and lemons, for instance, the "quarters" correspond with the chambers of the ovary in the flower, and their juicy flesh is, surprisingly enough, the product of a number of swollen hairs arising from the fruit-walls and filled with a sweet sap. In gooseberries and pomegranates the outer seed-coats become fleshy and make up the whole, or a great part of, the juicy pulp.

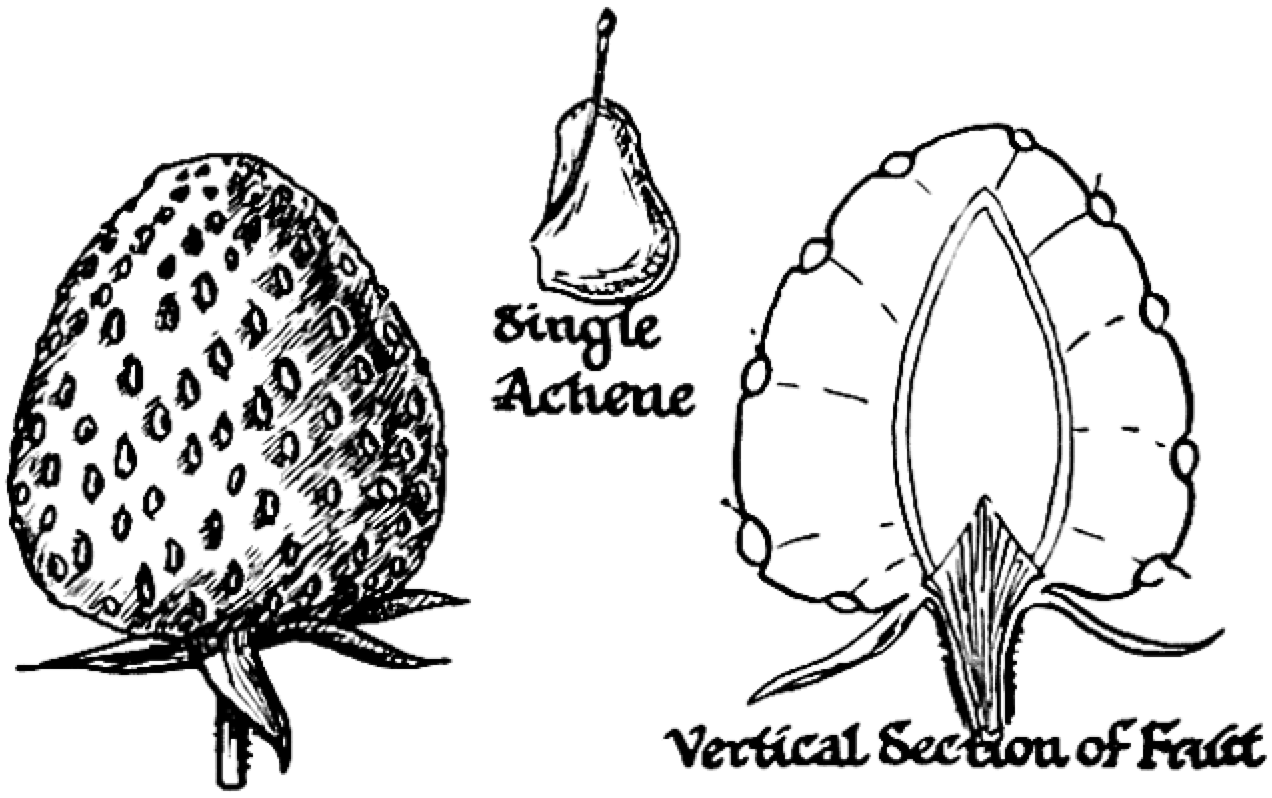
When we know a little botany, we can find much to think about in an ordinary dish of dessert. Apples and pears are commonplace enough, yet they have their surprises. Cut an apple across at right-angles to the stalk, and then examine how it is constructed. The thin outer skin encloses the sweet, fleshy part, and then comes the tough core which contains the seeds. This type of fruit is called a *pome* and it has this peculiarity: the skin and the greater part of the flesh are not formed from the ovaries at all. In the Apple-blossom the top of the stalk is hollowed out into a short tube. The tube encloses the ovaries and bears the sepals around its mouth above them. It is this insignificant tube that is responsible for the skin and the bulk of the flesh of the succeeding fruit. After the flower is fertilised the tube grows enormously, swelling out around the ovaries and completely enclosing them. You can recognise what was once the mouth of the tube by the remains of the sepals which persist on the top of the fruit. The matured ovaries themselves are easily distinguished in the five parts of the core, each of which contains one or two seeds. Hawthorn "berries" (which are *not* berries, but pomes, in the botanical sense) are formed in the same way. The tube at the top of the flower-stalk forms the skin and the bulk of the flesh, but the matured ovary walls, which, in the fruit, enclose the one or two seeds, become bony, instead of merely tough as in the apple and pear.

In the hips of the Wild Roses the scarlet, flask-shaped vessel develops similarly from the tube at the top of the flower-stalk, but the interior is quite different and so the fruit is not called a pome. The numerous separate ovaries of the flower become hairy, one-seeded achenes, and these are enclosed snugly within their glossy case to form a compound fruit. I like what one of the quaint old writers of other days said about the hips of Roses: The "Heps", he wrote (they used to spell pretty much as they liked in those happy days), " maketh most pleasant meats or banqueting dishes, as tarts and suchlike, the concoction whereof I commit to the cunning cook, and teeth to eat them in the rich man's mouth ".

The Strawberry is another compound fruit. The flower contains numerous separate ovaries set on the enlarged top of the stalk within the ring of petals. As the fruit ripens, this enlarged top swells up till you wonder when it is going to stop. Well, it stops when it has become the red and luscious pulp that makes such an appetising dish with about an equal quantity of sugar and a similar amount of clotted cream. The " pips " dotted over its surface are the matured ovaries, or achenes, each containing one seed.



Rose " Hip ", showing Achenes



Strawberry

Many years ago my uncle went to stay with some friends in the West Country, and he obtained an invitation for Janet and me as well. The morning after our arrival Janet and I got up frightfully early and stole down to the Cherry-orchard. I am not going to admit that we hoped to find no one about at such an hour, or that we were the least bit vexed to discover a gardener posted there with a gun.

" Good morning," said he, and " Good morning," we replied politely; and Janet added " What *are* you trying to shoot with that gun ? "

" I bain't trying to *shoot* nothin', miss," he said. " I'm scaring off they blackbirds from the cherries."

We had quite a long talk with him then, and were quite surprised to learn that, in cherry-time, someone had to be on duty with a gun from dawn till eve, or the birds wouldn't leave a cherry on the trees. Even while we were talking we saw several blackbirds come slinking up like the robbers they are, but they flew off with a chorus of " alarm " cries as the gardener's gun shattered the early morning silence with a bang.

We told Uncle Fred about this when he came down, and his surprising rejoinder was " Yes, it'd be a pity to lose the cherries; but I wonder how the trees feel about it? "

" The trees! " I echoed. " Why, what does it matter to them? "

" It matters everything, old chap. You see, the trees *want* the birds to eat their fruit, because then they scatter the seeds."

That was a new way of looking at it for us, so he went on to explain why trees and other plants produce drupes and berries and other fleshy fruits. They make them attractive, particularly to birds (who, of course, have the best means of access to them when they grow high up on trees), by their bright colours and sweet and juicy flesh. The flaming reds and scarlets of, for instance, the " berries " of the Hawthorn and Mountain Ash and the " hips " of the wild Rose ensure that those fruits shall not be overlooked. Plants, you see, believe in advertising their wares. Conspicuous hues, however, are by no means *essential*, for even without them the birds will soon find out where a feast awaits them. Blackbirds have a perfect passion for cherries, whether red or black, and thrushes find the black Elder-" berries " and black currants just as irresistible as red currants.

But, though the plants offer their fleshy fruits freely, ample care is taken that the seeds in them (which are the main concern) shall come to no harm. For one thing, the birds are kept away in the early stages of ripening by rendering the flesh harsh and sour. It is not until the seed is ripe that the flesh becomes temptingly sweet. Possibly you have discovered that for yourselves. Then, the seeds themselves are protected by the hard " stone " or other indigestible covering. Accordingly, when the flesh of the fruit comes to be devoured, the seeds are rejected or otherwise scattered without injury. It is not difficult to appreciate how effectively this work may be done—all unconsciously—by the birds when you consider the distances they travel on the wing whilst bearing off their plunder. Mark what happens when birds feed on the scarlet hips of the wild Roses. They get some of the hard enclosed achenes on their beaks, but these are so irritatingly hairy that, to get rid of them, they wipe their beaks vigorously on a branch, whence the achenes will probably fall to the ground. Sometimes, I think, the bigger birds must wrench off the entire hip, or at all events a good hunk of it, and bear it off to consume at leisure; for you may find old nests littered with the indigestible achenes which they have rejected. We ourselves help to scatter seeds when we eat fruit, for we carelessly throw the seeds away; though I doubt if our service is as effective as that of the birds in their widespread activity.

The Mistletoe has a special feature that I must tell you about, because it almost makes the plant appear as if it possessed human foresight. Part of the flesh of the berry surrounding the seed is exceedingly sticky, so that the latter adheres provokingly to the beak of any bird that feeds on the fruit. To rid itself of the nuisance the exasperated creature repeats the performance I described in connection with the achenes of the Rose, and the seed becomes fixed on the branch of the tree—the very situation in which the plant prefers to grow. It seems almost as effective a method as if the Mistletoe had deliberately wrapped up its seed in a parcel, tied a label on it and given it to the bird for delivery.

Janet has just thrust under my nose some rhymes she wrote when we were first learning about fruits and seeds and their dispersal. She calls them

Nursery Rhymes for Botanists

Ring-a-ring-o'-Roses,
The birds will eat the hips
And, when they peck the apples,
They will scatter all the pips.

Sing a song of sixpence
(That's the Woolworth cry).
Four and twenty blackbirds
Will make the cherries fly.

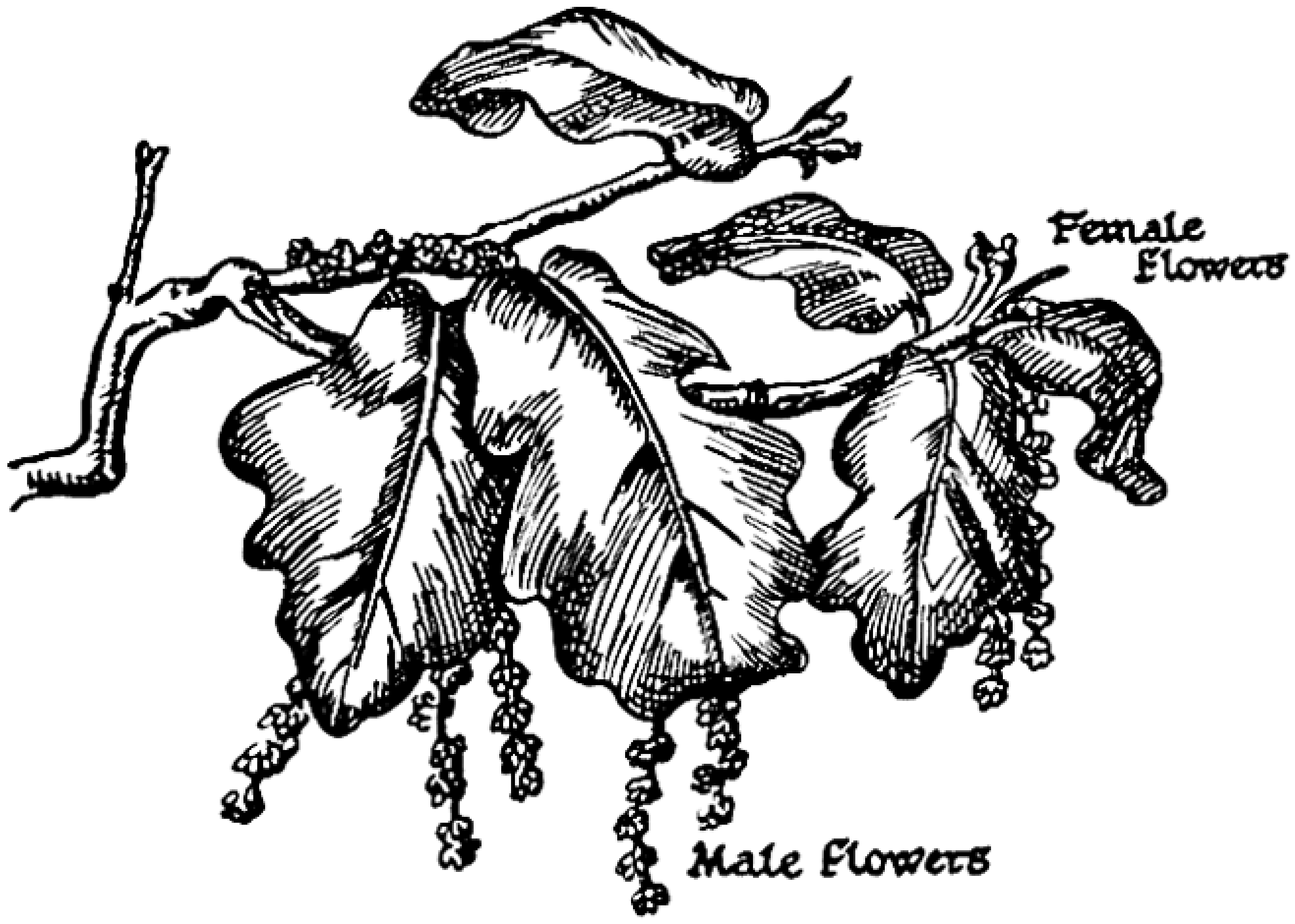
Mary had a baa-lamb
That followed her to school.
It kept her busy combing burs
Entangled in its wool.

Little Jacky Horner
Gave a dismal groan.
" Plums are drupes," he murmured;
" I feel it by the stone."

" Mary, quite contrary,
How does your garden grow? "
" Why the stems grow up in the air, of course,
And the leaves where there's room to spare, of course,
And the flowers wherever they care, of course,
And the roots go down below
How does my garden grow indeed!
How else did you think 'twould grow? "

Mary certainly seems to deserve being called " contrary ", so I think we had better leave her to attend to her gardening and continue our own studies. I have already incidentally mentioned another kind of fruit, the *nut*, and now we can examine some further instances of it in the Oak, Hazel and Beech, all of which bear separate staminate and pistillate flowers. We do not usually think of acorns as nuts, but botanists include them in that type of fruit; for a nut is, roughly speaking, a fairly large fruit with a hard or leathery coat containing usually a single seed. In the well-nigh invisible pistillate flowers of the Oak the ovary is set in a scaly cup. After pollination the latter develops into the beautifully chased cup of the acorn. The ovary, which remains seated in it, becomes the woody shell of the nut, and the kernel is the ripened seed. Such are the small beginnings of the grandest of our English trees. Hazel fruits develop somewhat after the same manner. The ovary of the pistillate flower becomes the woody shell of the nut, the kernel is the seed and the prettily fringed husk is formed from the tiny scales which surrounded the ovary in the flower stage. In the stately Beech the pistillate flowers grow, two or three together, from the top of a scaly ball. When the fruit has developed, the ovaries harden into two or three brown, glossy nuts. The nuts are enclosed by the matured ball, which then forms a prickly case. In the autumn the case splits open into four parts to release its contents—much to the satisfaction of the pigs and squirrels who are impatiently waiting to devour them. In these three fruits, you will notice, the nuts are more or less enclosed by a stout covering (the cup of the acorn, the husk of the Hazel and the prickly case of the Beech), which is formed, not from the ovary of the flower, but from the scales which surrounded it. They afford useful protection to the ripening seeds. The bracts that act as kites to Hornbeam-nuts are developed in the same manner.

These three trees do not seem to have evolved any really satisfactory way of dispersing their fruits. In fact, it always seems to me that they simply *invite* the animal world to eat them, an invitation which the animal world accepts right readily. Pigs and squirrels and dormice and badgers devour the nuts as fast as the trees shed them, and so, it would seem, the painstaking trees have their season's labour for nothing. Yet it does not fall out altogether that way. Squirrels and other wild animals have a habit of carrying off the nuts in their jaws and burying them in secret hiding-places as a winter store. You remember what Titania, the Queen of the Fairies, said to Bottom in *A Midsummer Night's Dream*?



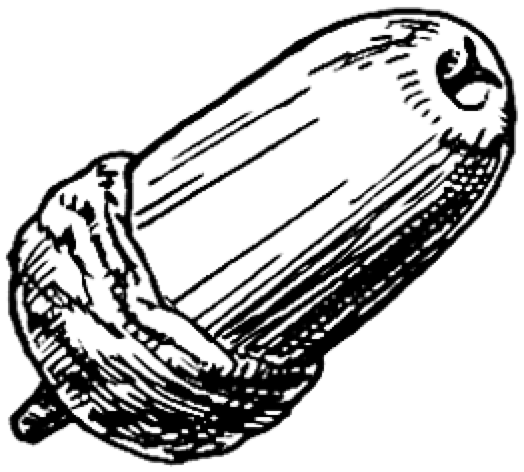
OAK

Female Flower

with stigmas and scaly cup

Male Flower

Male is staminate flower
Female is pistillate



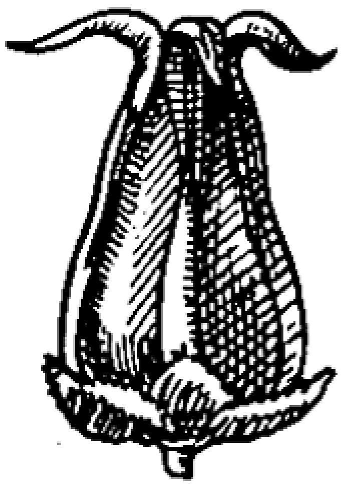
ACORN

At the top the remains of stigma can still be seen

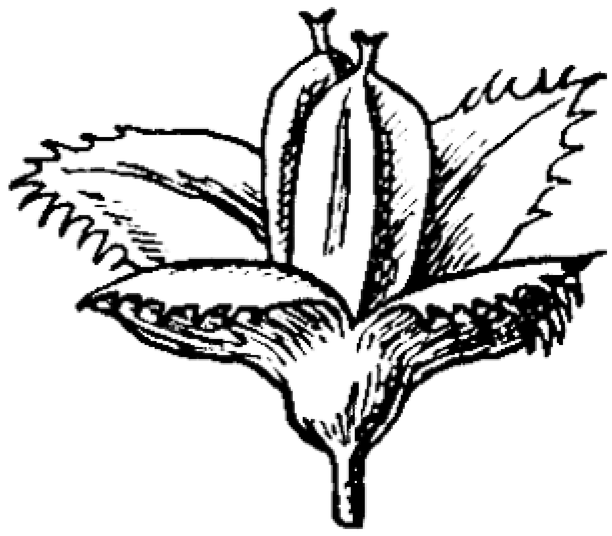
OAK FLOWERS AND FRUIT

> I have a venturous fairy that shall seek
> The squirrel's hoard, and fetch thee new nuts.

Very often the hurrying, and perhaps scared, little creature drops some of the nuts on the way, or it may suddenly decide to change its winter quarters and abandon its little hoard, or even forget about it altogether. Then some of those dropped or abandoned nuts may germinate and grow up into new trees, so that the animals do help the poor old trees to start off a few of their children in life. But it seems a stupid and wasteful method, and I should have thought a great giant like an Oak or a Beech would have lived long enough to think of something better. When, however, they grow near the banks of a river, the water sometimes helps to bear off the nuts to a considerable distance. I am always finding infant Beech-plants opening out their glossy, olive-green seed-leaves (like a neatly tied bow) along my river-bank; and, as the nearest Beech trees are a hundred yards higher up the stream, I think the water must have brought them down to me. Rivers and ponds often serve plants, especially water-plants, in dispersing their fruits and seeds.



Pistillate Flower of Beech



Beech Fruits

You see, then, as the result of our long ramble, that not only the wind, but many members of the animal kingdom, are unconsciously drawn into the plant's service in scattering their seeds for them. Even ants are said to be enlisted for the work. The Gorse, for instance, has a small, oil-containing swelling on its seed-coats. This appeals to the appetite of the ants, who drag off the seeds, intending to take them to their nests. They drop a good many on the way, in accordance with their fussy habit, or they may be unable to resist the temptation of stopping to devour the oily body there and then. In any case the young plant in the seed is left unharmed, and in this manner the seeds get widely scattered along the ant-runs.

Nature is a world of great marvels contained in small things, and the more you study fruits and seeds, the more deeply you are impressed by the astonishing ingenuity that shapes and adapts them for the purpose they are intended to fulfil. Not the least part of the wonder and mystery that surrounds them lies in this fact: The plants are rooted in the soil and denied that power, which animals possess, of moving from place to place. Yet, when it becomes necessary for their children to be settled in distant parts, their structure enables them to overcome the handicap which Nature imposes and to equip their offspring with the means of travel.

It is quite an absorbing pastime to draw the winged and other fruits we have been investigating. Fruits such as the Apple, Pear, Rose and Strawberry can be cut down through the middle and shown in section.

So, too, a walk becomes all the more interesting if you search for Sycamore, Ash and other winged fruits and see who can find those which have flown farthest from the parent plant. Janet and I used to make a competition of "hunting" Sycamore fruits in this way, and I believe that, when she went out alone, she used to play against herself. We also staged exciting aeroplane contests by launching Sycamore fruits, sometimes on a still day, at others on a windy one, and measuring their flight.

CHAPTER XII

FAMILY GATHERINGS

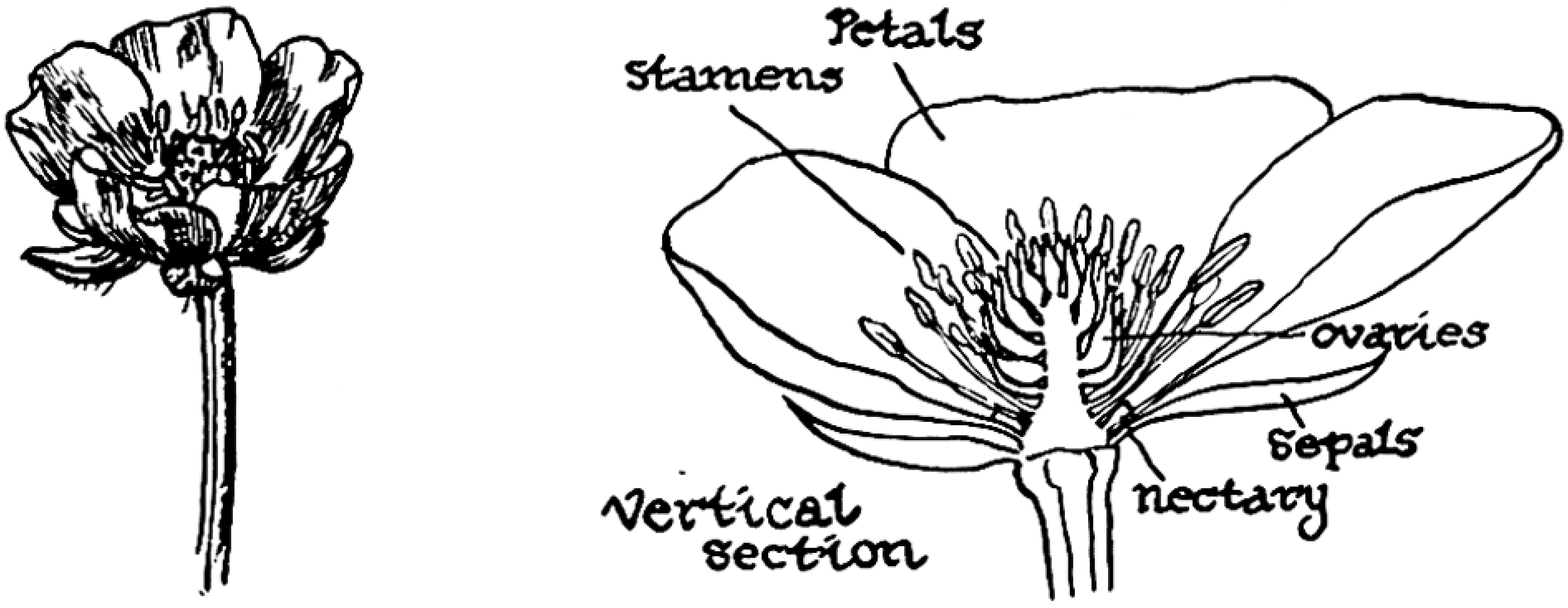
I AM afraid you will decide that this book has an unhappy ending, for this, the last real chapter, is all lessons. The best I can say about it is that it is a very short chapter, and that, as it tells about the *classification* of plants, it will be a real help to you in identifying wild flowers.

There are well over a hundred thousand flowering plants in the world (though less than two thousand are native to Great Britain), and botanists have arranged them in a number of separate groups. They have done this, partly to make them more manageable for purposes of study and reference, and partly for another reason. Plants show family resemblances to each other just as human beings do, and so, in classifying them, the botanists have sought to arrange the individuals in family groups.

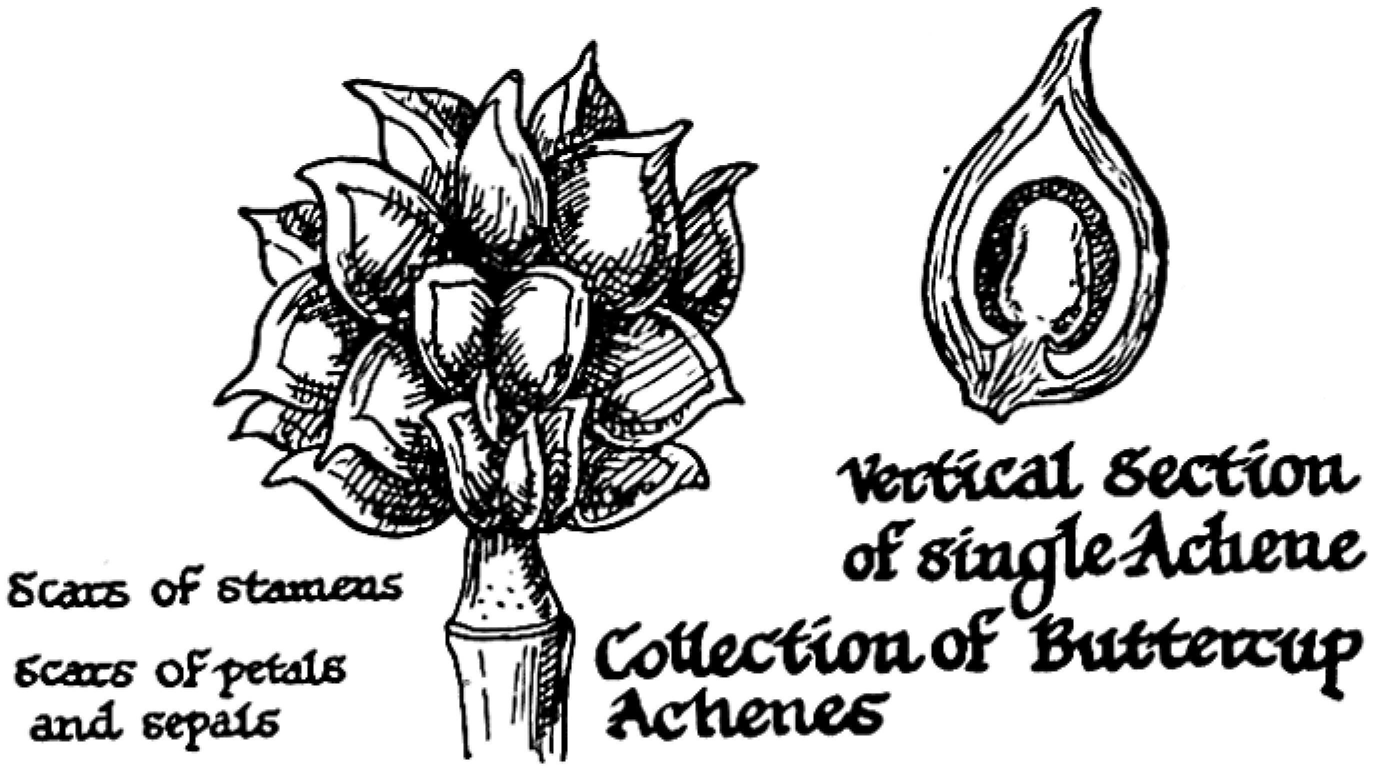
You have already learned of the first great division into monocotyledons and dicotyledons and how, in the main, the plants of those two groups are distinguished from each other in their seeds (p. 14), roots (pp. 22, 34 and 39), stems (p. 70), leaves (p. 73) and flowers (p. 105). Now we come to the further division into *Families*, each made up of plants which possess important structural features (in leaves, flowers, fruits, etc.) in common. There are a great number of these Families, and we cannot deal with them all now; but you will find some of the common characteristics of the flowers and fruits of a number of the principal Families set out below for you to study at leisure and learn by instalments.

DICOTYLEDONS

The Buttercup Family. All the flowers of this Family are what is called *hypogynous*. *Hypo* is a Greek term for " under ", and *gynous* indicates the ovary. In hypogynous flowers the sepals, petals and stamens spring from *beneath* the ovaries, the ovaries themselves being, accordingly, described as *superior*. The sepals and petals are separate from each other, or *free*. The flowers contain both stamens and pistils, which are usually numerous. The fruits are mostly a collection of *achenes* (see p. 143) or of *follicles*—*i.e.*, 1-chambered pods which split open along their inner edge. The Family includes the Clematis, Anemones, Buttercups, Marsh Marigold, Columbine, Larkspur, Monkshood, etc.



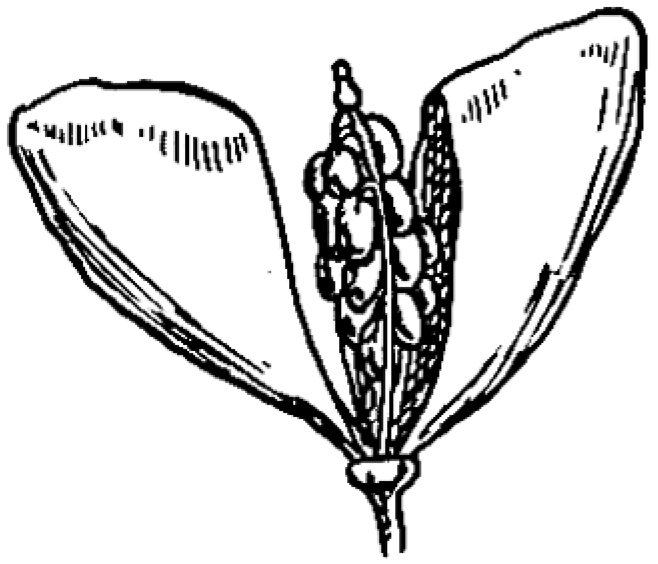
BUTTERCUP FLOWER


Vertical Section of single Achene
Scars of stamens
Scars of petals and sepals
Collection of Buttercup Achenes

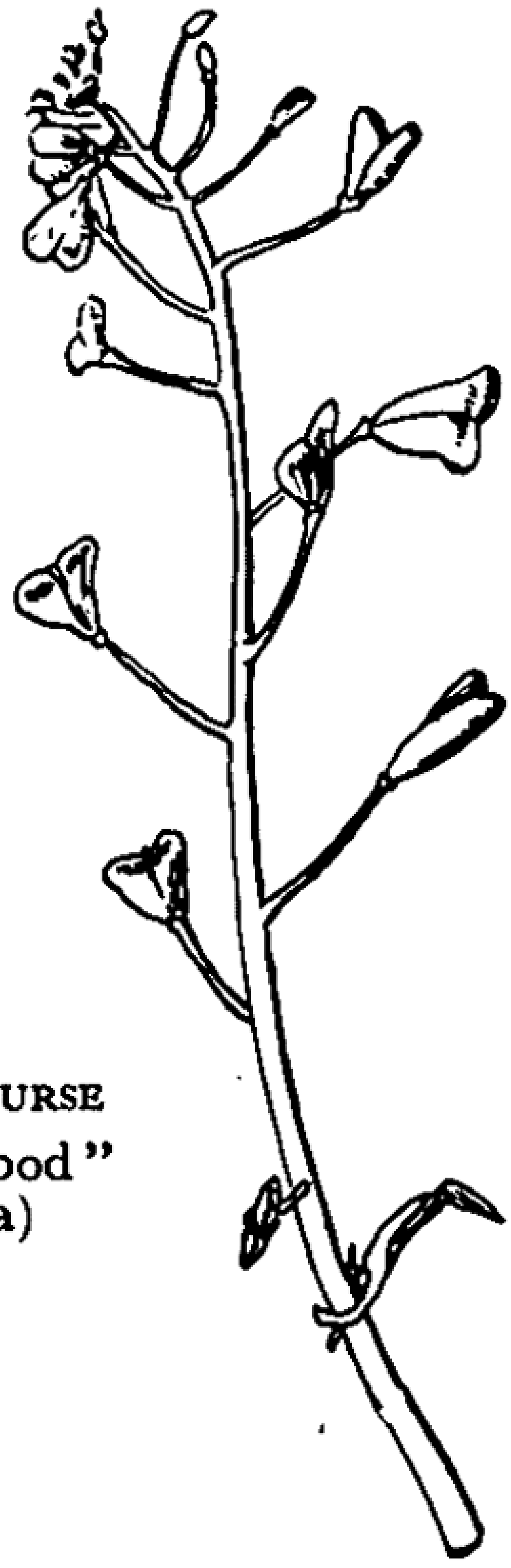
FOLLICLES OF MONKSHOOD

The Wallflower, or Crucifer, Family. The flowers are hypognyous and generally similar in construction to the Wallflower, described on p. 102. The petals, which are free, are arranged cross-wise, hence the name Crucifer, which means "cross-bearing." The fruit is either a *siliqua*—*i.e.*, a long and narrow 2-chambered pod which splits open along both edges from below upwards (see p. 136)—or a *silicula—i.e.*, a short and broad pod which splits open in the same manner. The Family includes the Stocks, Wallflower, Cresses, Lady's Smocks, Mustards, Cabbages, Cauliflowers, Turnips, Shepherd's Purse, Radish, etc.

The Pea and Bean Family. The flowers are slightly *perigynous. Peri* is a Greek term for "around". In perigynous flowers the expanded top of the stalk is hollowed out into the shape of a cup or basin, the ovary stands at the bottom and the sepals, petals and stamens are inserted *around* the rim. In this case also the ovary is superior. The general structure of the flowers is similar to the Clover, etc., described on pp. 115 to 118. The fruit is a *legume—i.e.*, a 1-chambered pod, which usually splits open along both edges (see p. 135). The Family includes the Laburnum, Gorse, Broom, Rest-harrows, Clovers, Trefoils, Vetches, Peas, Beans, etc.



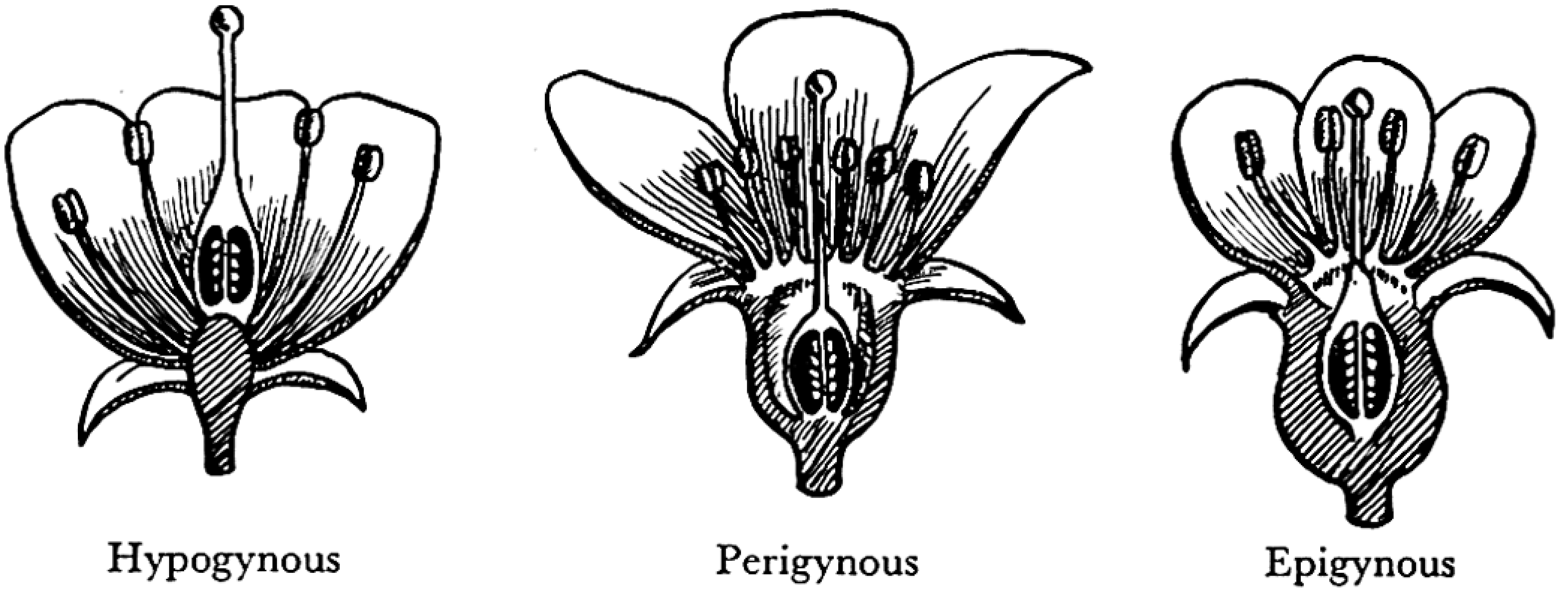
Dehiscence of Silicula

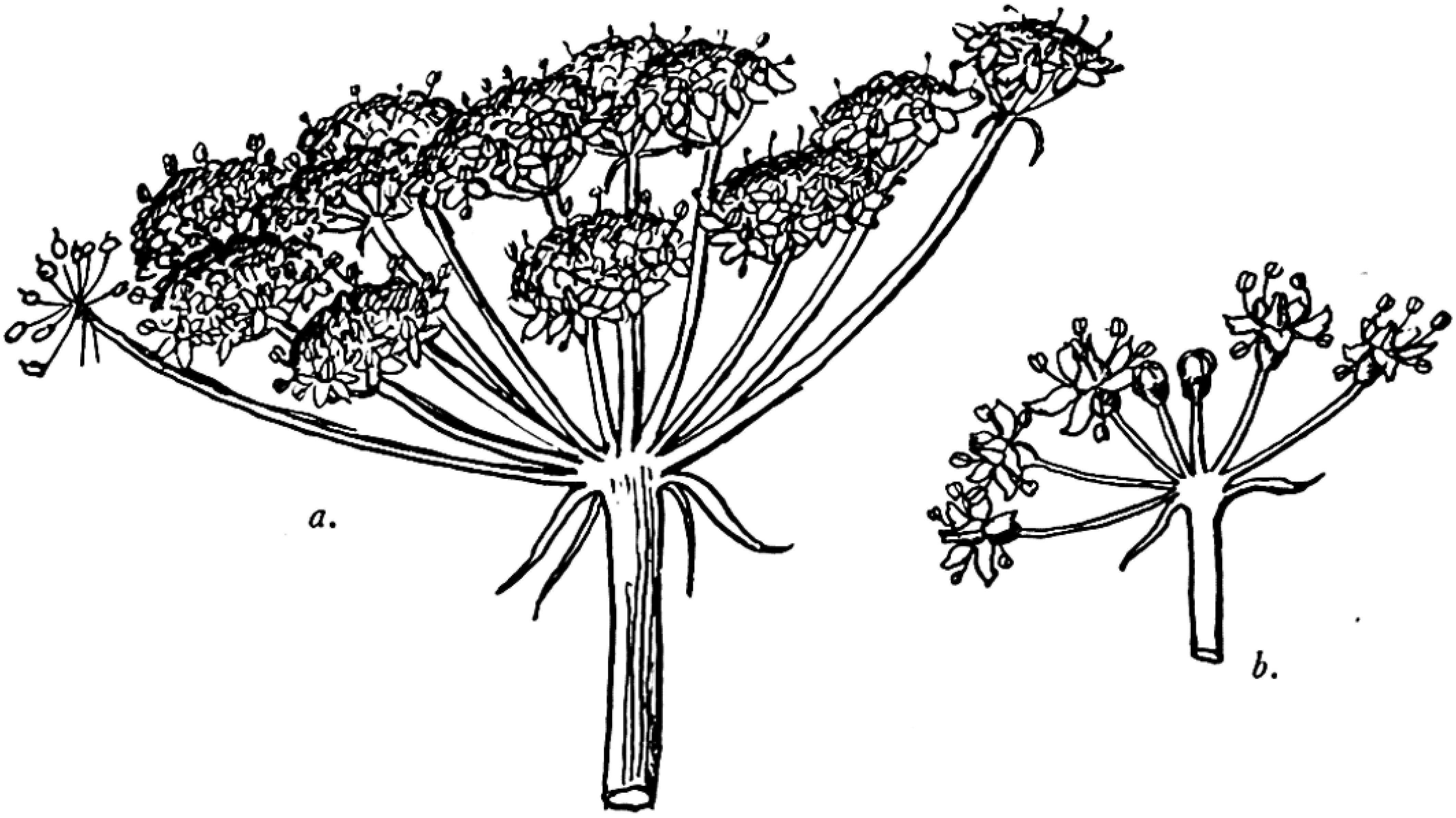


SHEPHERD'S PURSE
Splitting of "pod"
(or silicula)

The Rose Family. The flowers are most commonly perigynous, though in the Apple, Pear, etc., they are *epigynous. Epi* is a Greek term for "upon". In epigynous flowers the expanded top of the stalk is not only hollowed out, but it completely encloses the ovary and joins up with it, while the sepals, petals and stamens are inserted *upon* the top. In this case the ovary is *inferior.* The flowers mostly contain numerous stamens and pistils, together with, usually, 5 free sepals and 5 free petals. The fruits are of various kinds—*e.g.*, in the Plum, Cherry, etc., a *drupe* (see p. 151); in the

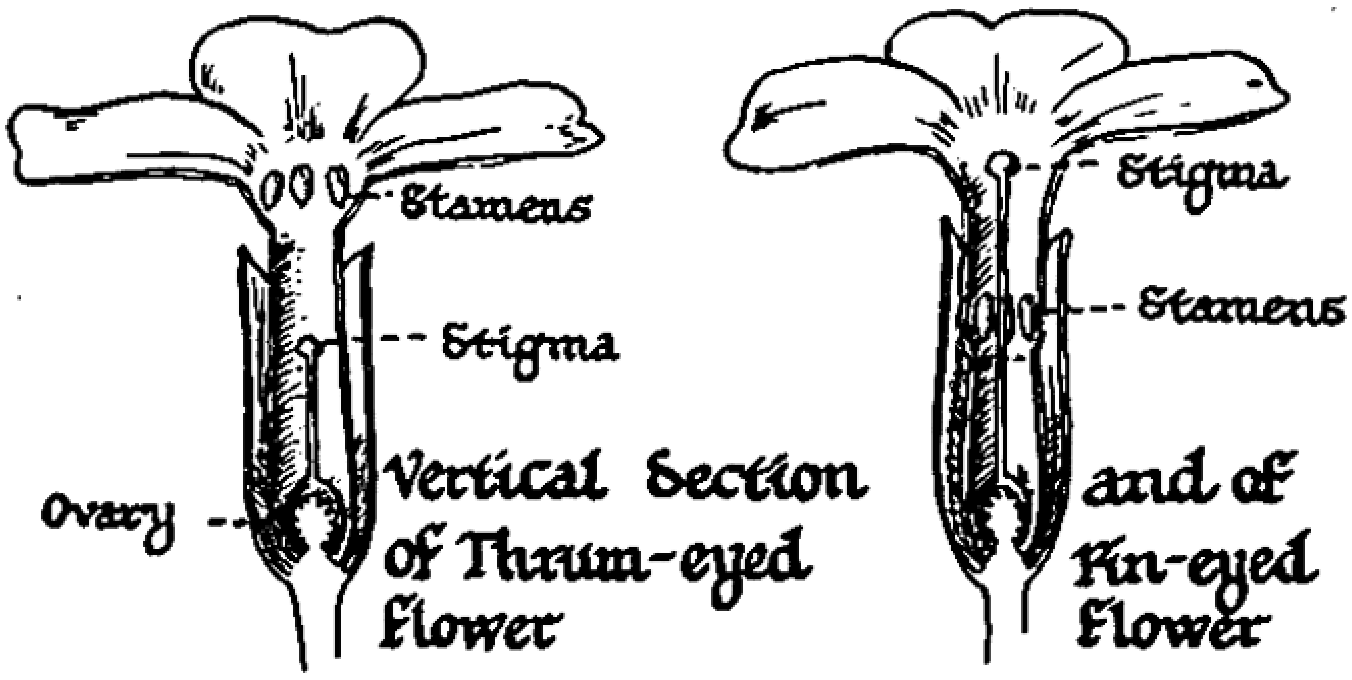
Blackberry, Raspberry, etc., a collection of *drupels* (p. 151); in the Herb Bennet, Cinquefoil, Rose, Strawberry, etc., a collection of *achenes* (pp. 143 and 153); in the Meadowsweet, etc., a collection of *follicles*; in the Apple, Pear, etc., a *pome* (p. 153). In general the Rose Family features accord with those of the Buttercup Family, except that the latter have hypogynous flowers and the former a variety of fruits.





Hogweed
a. Compound umbel. *b*. Simple umbel

The Umbellate Family. The flowers are arranged mostly in the form of a *compound umbel*. A *simple* umbel—*e.g.*, Ivy—consists of a head of flowers whose stalks all spring from about the same point on the top of the main stalk, rather like the ribs of an umbrella. A *compound* umbel consists of a number of simple umbels arranged in one head. The individual flowers in this Family are small, epigynous and usually white or yellow, with 5 minute free sepals, 5 free petals, 5 stamens and a pistil with 2 styles and an inferior 2-chambered ovary. The fruit splits into two *achenes*. The Family includes the Celery, Parsleys, Caraways, Fennel, Samphire, Angelica, Parsnips, Pig-nut, Chervil, Carrot, Hemlock, etc.



TWO TYPES OF PRIMROSE FLOWER

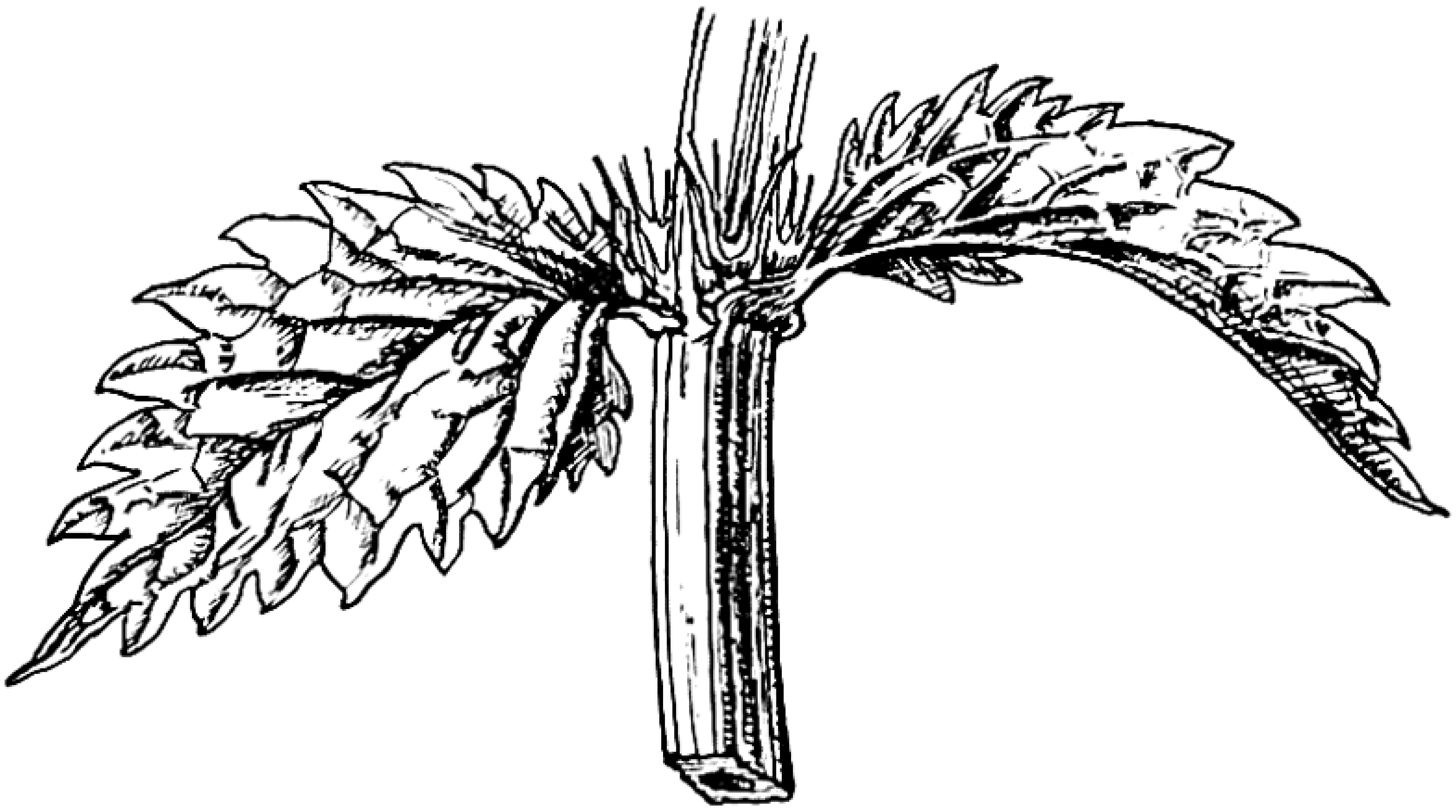
The Composite Family. The name means "compound" and is given to the plants of this Family because their flower-heads are composed of a number of separate flowers, or florets, massed together, as in the Daisy and Dandelion (see p. 120). There are three principal forms of flower-head: in the Dandelion, Hawkweeds, etc., all the florets are epigynous, strap-shaped and generally as described on p. 120. In the Burdock, Hemp Agrimony, etc., all the florets are tubular, but otherwise similar in general structure to those of the strap-shaped florets. In the Daisy, Ragwort, etc., the central, or disc, florets are tubular,

PRIMROSE

4

while the outer, or ray, florets are strap-shaped and without stamens. The fruit is an *achene* (see p. 142). The Family includes the Fleabane, Ox-eye Daisy, Chamomile, Yarrow, Tansy, Colt's-foot, Groundsel, Thistles, Knapweed, Cornflower, Goat's-beard, Chicory, etc.

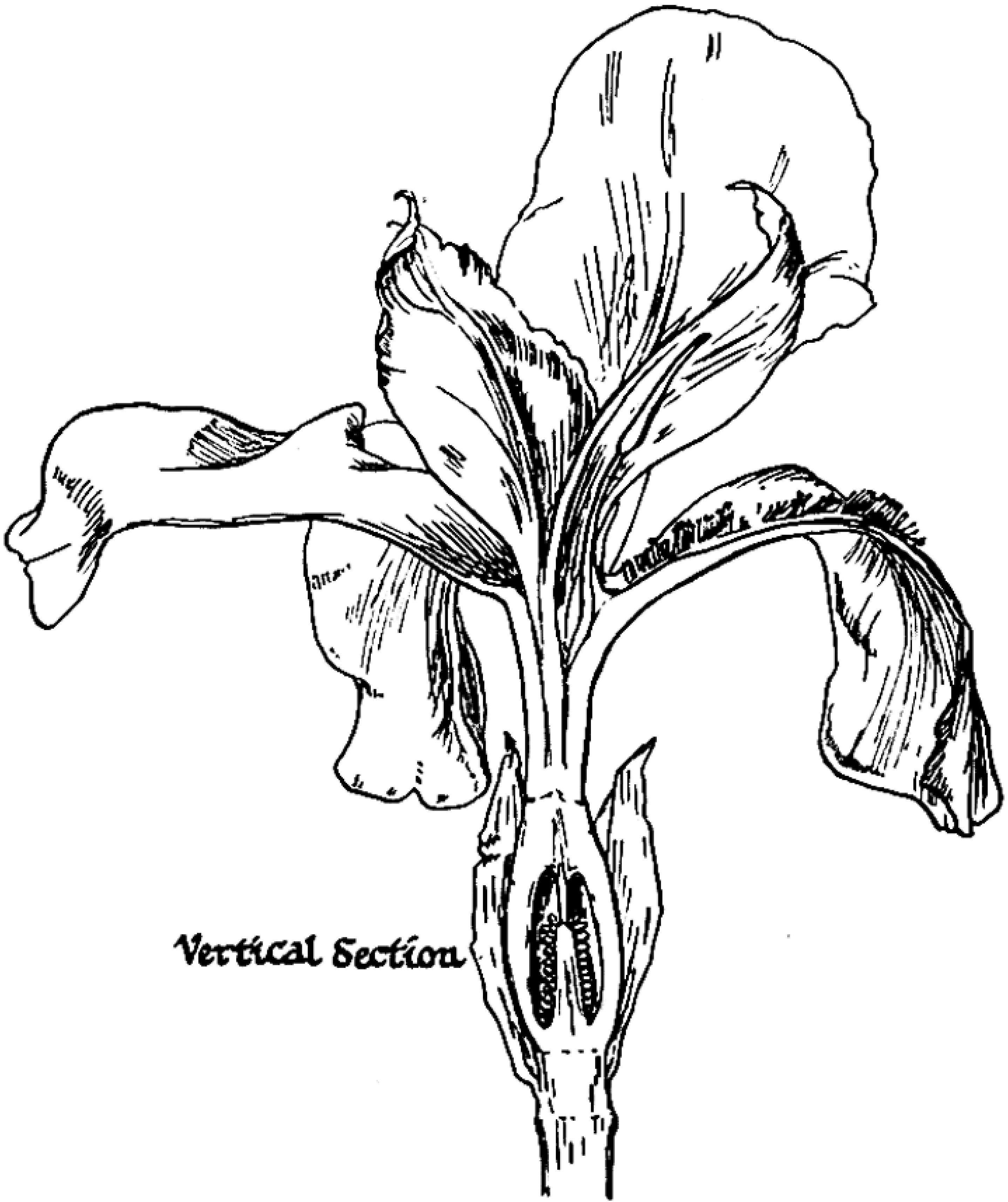
The Primrose Family. The flowers are hypogynous and usually have 5 united sepals, 5 petals more or less joined together, 5 stamens and a pistil with a single style and a superior 1-chambered ovary. The fruit is a 1-chambered *capsule* (see p. 137). The Family includes the Primrose, Cowslip, Yellow Loosestrife, Scarlet Pimpernel, Brookweed, etc. The Primrose has two types of flower designed to further cross-pollination.



SQUARE STEM OF DEAD NETTLE

The Figwort Family. The flowers are hypogynous and usually of irregular shape. They frequently have 5 united sepals, 5 petals, which also are joined together, often in the form of two lips, and 4 stamens (2 long and 2 short). The pistil has a single style and a 2-chambered, superior ovary. There are, however, several important exceptions—*e.g.*, the Mulleins have 5 stamens and almost regular flowers; the Speedwells have 2 stamens and 4 petals. (See p. 119.) The fruit is a 2-chambered *capsule*. You should compare this Family with the next one. The Family includes the Snapdragons, Toadflax, Figworts, Foxglove, Eyebright, Yellow Rattle, etc.

The Labiate Family. Labiate means " lipped " and is applied to this Family because the 5 petals of its flowers are almost always joined together in the form of two lips. The flowers are hypogynous, and usually have 5 united sepals, 5 petals, 4 stamens (2 long and 2 short) and a pistil with a single style and a superior ovary with 4 lobes (see p. 118). The fruit splits into 4 nutlets, and this is the feature that most clearly distinguishes the Family from the Figwort Family. (The stems, too, are always square and hollow and the leaves in pairs. These features are found in the Figwort Family, but they are not so constant.) The Family includes the Mints, Thyme, Ground Ivy, Self-heal, Woundworts, Dead Nettles, Wood Sage, Bugle, etc.



IRIS
This shows a stamen and the petal-like styles

MONOCOTYLEDONS

The Lily Family. There is no clear distinction between sepals and petals, so the two features are spoken of together as the *perianth.* The flowers are hypogynous, and generally have a perianth of 6 parts, 6 stamens and a 3-chambered, superior ovary. The fruit is either a *berry* (see p. 151) or a *capsule.* The Family includes the Herb Paris, Solomon's Seal, Lily of the Valley, Asparagus, Fritillary, Tulip, Squill, Bluebell, Garlic, etc.

IRIS

CROCUS

The Iris Family. The flowers are similar to those of the Lily Family, but are epigynous (and accordingly have an inferior ovary) and possess only 3 stamens. The Iris has 3 curious styles resembling petals. The fruit is a *capsule.* The Family includes the Iris, Gladiolus, Crocus, etc.

. . . .

Each Family is further divided into groups of plants which resemble each other still more closely, each group being called a *genus* (plural *genera*). The distinguishing features of the genera are best studied in a book, called a *Flora*, devoted to the detailed description of wild flowers. Each distinct kind of plant in a genus is known as a *species*. Thus, all the individual Viper's Bugloss plants you see constitute the species of that name.

CHAPTER XIII

A NEW WORLD

When Uncle Fred taught me some of the secrets of the plants, I felt that he had opened a door with a golden key and admitted me into a new world. And that, I fancy, is going to be your experience too. When you run out into the smiling fields and the woods, you will feel now that you understand something of the hidden life of the flowers. They are no longer just pretty blooms to be plucked for a nosegay; they are your intimate friends, whose character and habits have become familiar to you. You have discovered that every plant, whether it be great or small, is, for all its quiet manner and apparent idleness, industriously absorbed in the work of growing and rearing a family. You will be able to imagine its hidden roots busily taking up the water and salts of the soil, while the leaves labour throughout the day capturing the invisible chemicals of the air and compounding the food on which the plant lives. You will see the stem performing its varied duties of support and reproduction and food storage, and you will be able to study the blooms as they work to produce the seeds that represent the plants' children.

Indeed, I think you will begin to feel that you yourself have become the centre of a whole world of unsuspected activities. When you watch the birds busying themselves in the laden fruit-trees, you will know that something more is happening than the mere filling of their crops. When you feel the breeze rustling past you in the golden summer days, you will think of the pollen it carries to the waiting flowers; and, in the autumn, you will remember that the boisterous gales bear something more than dying leaves upon their wings, for they carry the ripe fruits of the plants as well, wafting them to distant homes where they may germinate and multiply their race.

The realm of Nature is one immense family in which each member, consciously or unconsciously, is working hand in hand with the others for furthering the preconceived design of the whole. All these details that we have been studying are minute parts of one great ordered scheme for preserving and improving all the forms of life on our planet, whether they belong to the animal or to the vegetable kingdom. And each of you is one of the family. The life that pulses in you so joyously flows also in the animals, the insects and the plants. The simple savages that lived in the early days of the world (and many that live to-day in remote uncivilised parts) had a stronger sense of their kinship with Nature than we can now experience. They believed, quite simply, that some at least of the animals and fishes and plants were their own brothers and sisters, having feelings like theirs and possessing often the power of speech. They thought there were spirits dwelling in the great forest-trees and that, when their parents died, they took up their abode in some particular tree, and they worshipped the trees accordingly.

We need not go so far as that in our sympathy with the wild creatures of Nature, but we can at least realise that the plants, being living and labouring creatures like ourselves, share with us the activities and the needs of a common life, growing and eating and drinking, and breathing and producing children and despatching them into the world.

I have dwelt many times on the ways in which plants resemble human beings and the animals of the wild. The most obvious *habit* that distinguishes them from animals is that, as a rule, they have no power of moving about; but even this distinction does not always hold, for, as Uncle Fred told us, there are certain minute water-plants that swim. A greater and more important distinction between green plants and animals is that the former can manufacture food from the " raw " chemicals of the universe, while the latter can only absorb their food when it has been made up for them by the plants.

But, however much or little you may be disposed to grapple with these larger aspects of Nature, you have her entrancing domain open to your exploration; and, if you cannot understand all the mysteries that start up at your feet, you can at least spend the happy days in seeking fresh knowledge that is full of interest. Which is what I am going to leave you to do—after I have given you a final taste of Janet's verses:

A NEW WORLD

There's been an awful [illegible]
In fact we've not begun
[illegible]—we're [illegible]
Botany for Fun.

The days are long!
You can't be melancholy
The world is full of flowers
[illegible] all the flowers are [illegible]

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